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OF THE

SECRETARY OF WAR

FOR

THE YEAR 1886.

IN FOUR VOLUMES.

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REPORT OF THE CHIEF OF ORDNANCE.

WAR DEPARTMENT, ORDNANCE OFFICE,
Washington, October 1, 1886.

SIR: I have the honor to submit the following report of the principal operations of the Ordnance Department during the fiscal year ended June 30, 1886, with such remarks and recommendations as the interests of this branch of the military service seem to require.

The fiscal resources and expenditures of the Department during the year were as follows, viz:

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Gross amount received during the fiscal year ended June 30, 1886, from sales to officers; from rents; from collections from troops on account of losses of, or damage to, ordnance stores; from Chicago, Rock Island and Pacific Railroad Company; from powder and projectiles (proceeds of sales); from sales of condemned stores; from testing machine, and from all other sources not before mentioned	66,541 93
Total	2,782,205 99
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Amount in the Treasury not reported to the credit of appropriations on June 30, 1886	4,257 70
Amount in the Treasury to the credit of appropriations on June 30, 1886	542,343 12
Total	2,782,205 99

[illegible]. Following are some representative results, using brown [illegible] powder:

Ballistic results.

Kind of powder.	Weight of charge.	Projectile.	Velocity at 150 feet from muzzle.	Pressure per square inch.
	Pounds.	*Pounds.*	*Feet.*	*Pounds.*
Brown [illegible]	100	183	2,135	29,450
	100	235	1,933	32,150
	100	[illegible]	1,787	32,800
[illegible]	100	[illegible]	1,929	32,950
[illegible]	100	[illegible]	[illegible]	35,430
[illegible]	100	[illegible]	1,702	[illegible]
[illegible]	100	235	2,017	37,[illegible]

ACCURACY OF FIRE.

In firing [illegible] of five shots each at a target 3,000 yards distant to determine which of the different rotating bands submitted for trial was [illegible] the following results were obtained with the band adopted:

Target [illegible] by [illegible] feet. Range 3,000 yards.

	Feet.
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

[illegible] within a circle [illegible] high degree of accuracy.

[illegible]

chase hooping, sent to the proving ground and fired with heavy charges. The most careful attention has been paid to enlargements of the bore within the unhooped portion of the chase. During the firing of the twenty-four rounds the bore was star gauged after the first, fourth, seventh, thirteenth, twenty-third and twenty-fourth rounds. Even after the thirteenth round the maximum enlargement in the unhooped chase was but $\frac{2}{1000}$ of an inch. After the twenty-fourth round for about 12 inches in the length of the bore near the muzzle the enlargement was $\frac{6}{1000}$ of an inch. This enlargement is in itself small, showing an extension of only $\frac{75}{100000}$ of an inch, per linear inch, or less than one-half of one per cent. of the ultimate extensibility of the metal after rupture, as determined by tests of bars cut from the tube forging itself. A careful consideration of the results, however, led to the conclusion that the chase should be hooped to the muzzle, having also in view the purpose of the Testing Board to fire the gun to extremity. This modification in the design will permit, with a suitable powder adapted to a high density of loading, of increasing the present powder charge, if desired, and will enable the Department fully to develop the ballistic properties for guns of this class. The gun has been returned to the West Point Foundry, where it is now in the lathe being turned for its chase-hooping.* It is expected that the trial will be renewed in about two months.

This 8-inch gun is made largely of imported steel. The first forgings imported were rejected as not up to our standard of what the metal should be. The machining of the steel and fashioning of the gun, was done in this country. The technical work, such as determining the specifications, and the details of the construction, the shrinkages, &c., and the daily supervision and inspection, was the exclusive work of ordnance officers. In the manufacture of high-power steel guns such as these no rule-of-thumb methods can be followed. Scientific study, and technical skill and devoted attention to the work can alone reach successful results. The few rounds already fired prove that the work was well done, and gives us every reason to believe that the qualities of steel required for guns and the manufacture of guns can be intrusted with entire confidence to the officers of this Department.

I may here remark, that, owing to the failure of the fortifications bill, and the consequent inability of the Department to procure new supplies of powder, it would have been impracticable to test this new 8-inch gun after its completion, except for the fact that the Department had an existing contract with the Messrs. Du Pont for a supply of brown powder.

*Since writing the above the chase of the 8-inch rifle has been turned down for the reception of its hoops, and after removing the necessary metal on the exterior it was ascertained that the bore had undergone considerable restoration, which has materially reduced the above-noted enlargement. This fact points to the existence of initial strains in the original tube, due probably to faulty treatment in manufacture, and which, acting in the same direction as the powder strains, caused an enlargement of the bore such as was not to be expected from the action of the powder alone.

Production of steel gun forgings.

The Midvale Steel Company, has completed its contract for the delivery of twenty-five sets of forgings for 3.2-inch B. L. field guns. The steel furnished has been of a superior quality, exceeding the requirements of the contract. These works have also completed all the parts for the 5-inch B. L. siege gun, excepting the jacket, and that will be delivered in November. A tube and trunnion hoop for an 8-inch B. L. rifle have also been successfully forged and accepted. The production of the 8-inch rifle jacket has been attended with considerable difficulty, and a number of failures have been experienced, this being the largest gun forging thus far undertaken at Nicetown. But the last attempt has, there is reason to believe, proved entirely successful, and the manufacturers have gained in compensation for their failures most valuable practical knowledge of how to deal with large forgings, and thus have broken fresh ground in the development of the steel industry.

Prior to ordering the trunnion hoop for the 8-inch gun, as the production of a forged steel trunnion hoop—at least of any considerable size—had not hitherto been accomplished in this country, and as it was very desirable to know accurately the mechanical qualities of such a forging, the Department procured from the Midvale Steel Company, for purposes of test, a forged trunnion hoop of about the same size as that required for the 8-inch rifle. When completed this trunnion hoop was sent to the West Point Foundry, where it was cut in half along a plane passing through the axis of the trunnions and perpendicular to the axis of the hoop. One of the halves was then subjected to thorough mechanical test by means of test specimens taken from various parts along the inner face, while the other half was subjected first to an elastic, and then to a strength test by being shrunk successively on two cast-iron cylinders. The results by both methods of test were satisfactory and demonstrated the ability of the Midvale Steel Company, to cope with these difficult forgings. Following are some results obtained from the 8-inch tube and trunnion hoop. The test specimens were taken tangentially, those from the tube being 3 inches long and of .364 of an inch diameter, and those from the trunnion hoop 6 inches long and of .364 of an inch diameter:

8-INCH TUBE—TENSILE TESTS.

	Elastic limit.	Tensile strength.	Elongation after rupture.
	Pounds.	*Pounds.*	*Per cent.*
Breech end:			
Outside	51,000	90,400	23.00
Middle	46,000	85,200	21.00
Inside	40,000	90,240	20.33
Means	45,667	87,813	21.44
Muzzle end:			
Outside	52,000	94,000	19.67
Middle	50,000	91,000	21.33
Inside	53,000	94,320	17.00
Means	51,667	93,333	19.33

8-INCH EXPERIMENTAL TRUNNION HOOP—TENSILE TESTS.

	Elastic limit.	Tensile strength.	Elongation after rupture.
	Pounds.	*Pounds.*	*Per cent.*
Outer end, A:			
Minimum	49,000	80,600	17.67
Maximum	57,000	93,920	22.17
Average	53,750	91,890	19.25
Center, C:			
Minimum	45,000	80,760	16.50
Maximum	56,000	91,960	19.33
Average	48,300	86,652	17.81
Outer end, B:			
Minimum	44,000	87,000	14.50
Maximum	48,000	89,000	20.30
Average	46,250	88,090	18.04

The results from the shrinkage tests of the trunnion hoop showed that, whilst the hoop was weakest in the vicinity of the trunnions, the hoop as a whole was adapted to purposes of gun construction, yet that due care must be exercised in the determination of the shrinkage to be employed, as an excessive shrinkage would tend to develop a set in the trunnion masses when the gun is fired. A full report on this experimental trunnion hoop, showing the locations of the test specimens and describing the tests, and giving the conclusions to be drawn from them, is contained in Appendix 26. Since the manufacture of the experimental trunnion hoop the Midvale Steel Company, has delivered the 8-inch rifle forged trunnion hoop, and a similar hoop for the 12-inch B. L. mortar, the end tests of which are nearly equal to those from cylindrical hoops. For full report of the operations at these works during the past year, see Appendix 23.

At the Cambria Iron Works the Department has had a lot of twenty steel hoops under manufacture since September 15, 1885. In this, their first attempt at the production of steel-gun forgings, the Cambria Works have encountered many obstacles, particularly so as the hoops are of considerable size and the specified qualities for the metal very high. But they are steadily completing their contract and fully meeting its requirements in spite of difficulties. A good part of the hoops have been delivered, and the remainder are in a forward state of completion. This establishment has also in hand for the Department a set of forgings for a 7-inch B. L. rifled howitzer, which will give them an opportunity for acquiring experience in the production of steel tubes and forged trunnion hoops. A full report of the operations at the Cambria Works during the past year, with an exhibit of the results obtained from the 10-inch rifle hoops is given in Appendix 24.

The status of the steel works which have thus far undertaken the production of gun steel is to-day about as follows: There is *one* establishment able, with present facilities, to produce all the forgings, and of the required qualities, for a steel gun of 8 inches caliber, and hoops of all sizes except the very largest and heaviest, and the breech mechanism and smaller forgings for all calibers. There are *two* establish-

REPORT OF THE CHIEF OF ORDNANCE.

WAR DEPARTMENT, ORDNANCE OFFICE,
Washington, October 1, 1886.

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STATIONS AND DUTIES.

The stations and duties of the officers of the Ordnance Department are as follows: Four at the Ordnance Office; thirty-nine at the arsenals, armory, and powder depots; nine on the Ordnance Board and at the foundries; six at the several military headquarters and ordnance depots; four at the Military Academy; one under the orders of the Secretary the Interior; one in the Life-Saving Service, under the Secretary of the Treasury.

The Ordnance Department provides the armament for our sea-coast defenses, and arms and other ordnance stores for the Army, the militia, the Marine Corps, all other Executive Departments to protect public money and property, and the forty colleges authorized by law to receive them for instruction.

SMALL-ARMS.

During the fiscal year ended June 30, 1886, 39,527 rifles, carbines, and shotguns have been manufactured at the National Armory. Repairing arms, providing spare parts, making swords, sabers, and miscellaneous articles must be mentioned as among its operations.

The Lee, Chaffee-Reece, and Hotchkiss magazine rifles had been in the hands of troops for trial during the previous year. In December last the reports of their trial having been received and properly tabulated and digested, (Appendix 35), the following report was made by this Office to the honorable Secretary of War:

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, D. C., December 15, 1885.

The honorable the SECRETARY OF WAR:

SIR: I have the honor to transmit herewith a tabular statement of the results reached in the trial of a number of each of the magazine rifles issued to the troops. These guns—the Lee, Chaffee-Reece, and Hotchkiss—were recommended for trial, in the order named, by a board of officers convened in 1881 under authority of law, and were distributed to the Army for the purpose by the Lieutenant-General of the Army.

The reports from 149 companies have been received, examined and tabulated, and the results are as follows:

Comparing the three magazine guns with each other the reports are:

For the Lee 55, Chaffee-Reece 14, Hotchkiss 26. As magazine guns therefore the reports are largely in favor of the Lee.

Comparing the magazine guns with each other and with the Springfield service rifle as *single loaders*, the preference is for the Springfield, as follows: For the Lee 5, Chaffee-Reece 0, Hotchkiss 1, Springfield 21.

Comparing the magazine guns and the Springfield *for all uses*, the preference is for the Lee 10, Chaffee-Reece 3, Hotchkiss 4, and the Springfield 46—being largely in favor of the Springfield.

In the column of objections in the tabular statement, will be found a brief of the objections given in each report.

After a careful consideration of these reports, I am satisfied that neither of these magazine guns should be adopted and substituted for the Springfield rifle as the arm for the service.

I have been and am an advocate for a magazine gun, but it would seem the part of wisdom to postpone for the present any further efforts towards the adoption of a suitable magazine arm for the service. The Springfield rifle gives such general satisfaction to the Army that we can safely wait a reasonable time for further developments of magazine systems.

Very respectfully, your obedient servant,

S. V. BENÉT,

Brigadier-General, Chief of Ordnance.

The 1,000 rod-bayonet rifles, new model, and improved sights, which have been issued are still under trial by the troops.

METALLIC AMMUNITION.

The attention of the Department having been called to the occasional inaccurate shooting of the carbine cartridge through Lieut. Frank Baker, the officer in charge of the proof of ammunition at the Frankford Arsenal, a series of trials was ordered with a view to discover and correct the cause of the inaccuracy. An exhaustive report on the subject prepared by that officer (Appendix 34) has led to the omission of the wads from future manufacture. Provision has been made to meet the changes required in both bench and hand reloading tools for reloading this ammunition.

The Morse cartridge, which has been under consideration by the Department for a number of years, has recently been so far perfected through the efforts of Mr. Morse that it has been decided to issue a number for trial with the troops. The manufacture of a suitable number for this purpose is now in progress at the Frankford Arsenal and they will be ready for issue at an early date.

During the past year forty-eight sets of bench reloading tools for metallic ammunition have been issued to posts, comprising all those of five or more companies and including eight posts of four or a less number of companies.

RIFLE PRACTICE.

The gold and silver medals offered as rewards for successful marksmanship in the annual department and division rifle contests have, as usual, been issued to the different headquarters in advance of the date of the contests, thus insuring their formal presentation to the fortunate competitors at the first parade after the conclusion of the competition.

During the year the new skirmish targets prescribed by Blunt's "Rifle and Carbine Firing" have been manufactured at the Rock Island Arsenal and supplied to the Army. They have been very generally approved and are so carefully made that they will probably meet all requirements in this respect for several years to come.

In consequence of the growing interest taken by the Army in rifle firing and the more general belief as to its great importance and necessity which is now prevalent, the demand upon this Department for the different materials requisite for practice has greatly increased. The

work of manufacture has, however, been so systematized that the Department has been able to promptly meet all demands and furnish liberal supplies, and as a consequence the rifle ranges at the different posts are now better equipped generally than at any previous time.

There is little doubt that at the present time the facilities offered to the soldiers of our Army are greater and more perfect than those enjoyed by other armies, and the result of having practically an army of marksmen is due in a great degree to this liberal supply of all the material for this most important element of the soldier's education—the effective use of his rifle.

THE MILITIA.

At the last session of Congress a bill increasing the annual appropriation for arming and equipping the militia to $600,000 passed the Senate, and is now pending in the House with an amendment fixing the amount at $400,000. This matter has been so often brought to the attention of Congress that the reiteration of the obvious reasons in favor of a more liberal appropriation is unnecessary. It is hoped that the bill now pending, with or without amendment, may become a law.

ARMOR PLATE EXPERIMENTS AT SPEZIA.

The necessary permission having been obtained from the Italian Government for representatives of the United States Government to be present at the trials, to take place at Spezia, of Gruson's chilled iron armor under the fire of the 100-ton gun, Capt. D. A. Lyle, Ordnance Department, was on the recommendation of this office, directed by the War Department to proceed to that place to witness the trials. These highly important trials occurred during the spring, and resulted in a success for the chilled iron armor against the forged steel projectiles from the 100-ton gun. Captain Lyle has submitted to the Department an interesting report on the trials, which will be published at an early day.

APPROPRIATIONS.

The aggregate amount appropriated for the past fiscal year under the heading "Ordnance, Ordnance Stores, &c.," was $400,000, and for some of the objects specified the amounts were found to be insufficient. The aggregate amount appropriated under this head for the present fiscal year is only $255,000—a reduction of about 40 per cent. from last year. I have stated in the estimates submitted for the next year that this sum is wholly inadequate, and needed work and manufactures cannot be undertaken in consequence.

PROCURING SUPPLIES.

Section 3709, Revised Statutes, requires all supplies to be procured after due advertisement and competitive bidding. This law enacted in 1861, when the contracts and purchases were of great magnitude, had

then and still has a good effect in securing a healthy competition among bidders and in insuring to the United States the needed supplies at fair prices, when the purchases are of any considerable amount. But there are many cases constantly occurring at our manufacturing establishments where small supplies are required, and where the expense of advertising largely exceeds, in some instances, the value of the purchases, to say nothing of the additional loss by the consequent delay in this mode of purchase. I refer now to the minor incidentals, the necessity for which cannot be economically anticipated.

To meet such cases, and in the interest of a true public economy I would recommend that section 3709, Revised Statutes, be amended by inserting after the word "services" on the first line the words "in excess of one hundred dollars," so that the section shall then read:

SEC. 3709. All purchases and contracts for supplies or services *in excess of one hundred dollars*, in any of the Departments of the Government, except for personal services, shall be made by advertising a sufficient time previously for proposals respecting the same, when the public exigencies do not require the immediate delivery of the articles, or performance of the service. When immediate delivery or performance is required by the public exigency, the articles or service required may be procured by open purchase or contract, at the places and in the manner in which such articles are usually bought and sold, or such services engaged, between individuals.

Existing law permits the Interior Department to make purchases in open market to the amount of $500.

THE ARMAMENT OF FORTIFICATIONS.

The Board on Fortifications or other Defenses appointed under the act of March 3, 1885, rendered its report to Congress on the 23d day of January last. That report gives an exhaustive survey of the subjects that came within the province of the Board, and closes with clear, definite, and practical recommendations, accompanied by estimates, which should they meet with favorable action from Congress, would result in placing our principal ports in a secure state of defense, and in insuring the production within our own borders, at an early day, of the steel forgings requisite for the construction of the heaviest armor and guns.

The report indorses the recommendation of the Gun Foundry Board touching the establishment by the Government of two gun factories, one for the Army and the other for the Navy; and Congress also by legislation at its last session, in enabling the Navy Department to begin the establishment of such a factory at the Washington navy-yard, practically endorsed, and gave effect to that recommendation. A bill embracing similar provisions with respect to the establishment of an Army gun factory at the Frankford Arsenal was indeed passed last session by the Senate, but failed to obtain the concurrence of the House, and still remains in conference. Under one provision of that bill $400,000 were appropriated for completing and testing the guns which the Department has now under construction, for procuring guns, carriages, powders, projectiles, &c., and "for the purchase, manufacture, and

erection of the necessary tools and machinery for the finishing and assembling of heavy ordnance at the Frankford Arsenal, Philadelphia, Pa." By still another provision $6,000,000 were appropriated, to be available for a period of six years from the date of contract, for the purchase of rough-bored, turned, and tempered steel forgings, suitable for heavy ordnance, adapted to modern warfare,—the amount appropriated to be divided equally between the Army and Navy. The features of this bill as a whole are judicious and well devised, except that the very important question of fortifications is wholly ignored. But no doubt great good would have resulted from the passage of the bill in its present shape by Congress. The want of machine shops under its own control, fully adequate to the manufacture of type guns of various calibers, has been a great obstacle to the Department in its experimental work and in the constructional development of heavy guns. Under the provisions of this bill a start would have been made in the right direction, by laying at least the foundation of a gun factory at the Frankford Arsenal, and which under a fostering legislation would be added to from year to year. Thus the effect of the annual appropriations would be cumulative, and the Department would ultimately possess a fully equipped and organized factory, capable of producing both type guns and, in limited supply, the guns for issue to the service. The advantages accruing to the Government from establishments of its own have been so fully and forcibly presented in the report of the Gun Foundry Board as to require no reiteration or enlargement here. It will suffice to say that an Army gun factory is a great want, and it is most earnestly recommended that Congress take such action at its next session as will place the Department on, at least, an equal footing with the Navy in respect to such an establishment. The appropriation of $6,000,000 for steel forgings is perhaps scarcely sufficient to arouse much competition among steel makers, but it would doubtless prove a healthful stimulus to those manufacturers who are now engaged in supplying the Government with gun forgings. The amount recommended by the Board on Fortifications or other Defenses for gun metal for the first year alone was $8,000,000, while for inaugurating the production of armor plates, laying the foundations for fortifications, manufacturing gun carriages, submarine mines, torpedo boats was $13,500,000, making the total amount recommended for the first year $21,500,000. In these recommendations of the Board this Departmeet fully concurs.

Through the failure of the regular fortifications appropriation bill to become a law at the last session of Congress, serious injury has been sustained by the Department, and its operations as regards the armament for fortifications, for the fiscal year 1886-'87, such as the completion and test of the experimental guns under construction, the further development of powders and explosives, and the alterations of carriages for mounting existing guns have practically ceased, except in so far as that work is continued over from last year by existing contracts.

And not only has the work come to a standstill, of itself a great evil, but the *personnel* of the Department, employed on the work, has been almost entirely discharged. The force of civilians employed at the proving ground, consisting of men of long experience in handling guns and explosives, and doing the technical work in connection with an ordnance proving ground, has been lost to the Department, and the operations now practicable at that point must be carried on by means of enlisted men taken from the arsenals, who will require very considerable instruction and practice to fit them for the proper discharge of their new duties.

At the Watertown Arsenal, where the Department has had under construction the experimental 10-inch wire guns, the alteration of sea-coast carriages, and the manufacture of gun-sights and other supplies pertaining to the armament of forts, work has practically ceased, and the large force of skilled men has been discharged. The expense and labor attending the recommencement of work, like the installation of new work, is very considerable, and is made apparent in the increased cost of the articles produced. The difficulty also of getting skilled men for such technical work, of organizing, of instructing, of getting the right man in the right place, and of determining the best and cheapest manner of doing the work—all matters of great moment—has to be again encountered and overcome after a period of enforced idleness. But the difficulty of procuring good men, when work is resumed, becomes more difficult than ever, from the feeling of uncertainty regarding the permanency of their employment.

The interruption of the work in hand has proved a source of great discouragement, nevertheless every effort has been continued to perfect the plans of the Department and to maintain the well-reputed interest and ability of its officers on these subjects, under the hope, which is believed to be well grounded, that this embarrassment is but temporary.

Following is a brief summary of the present condition of the work, and of the results obtained in experimental trials during the year.

Experimental 12-inch B. L. Rifle, cast iron.

The trial of this gun has been continued during the past year, under the supervision of the Board for Testing Rifled Cannon, &c., who have submitted a progressive report (Appendix 10). The total number of rounds thus far fired is 137; of which number 123 have been with the full charge of 265 pounds of powder, and 79 rounds with an 800-pound projectile. The mean pressure for one hundred observations has been 27,998 pounds per square inch of powder chamber, and the maximum pressure registered in any single round 34,400 pounds per square inch. This statement of course discredits the result obtained in the 5th round, where 47,250 pounds pressure per square inch was registered. But as in that round only the light charge of 150 pounds hex-

agonal powder, with a 700-pound projectile, was employed, and the velocity obtained was but 65 feet greater than in the preceding round, where with the same charge of powder, though fired under a somewhat less density of loading, only 24,600 pounds pressure was registered, it is clear that in this instance the indication of the gauge was erroneous. All the preceding rounds fired confirm this conclusion. The record was at the time reported as being unreliable from the fact that the gauge was displaced in firing, from want of a solid support. The different lots of brown powder tested have shown some variation from one another with respect to velocity and pressure; but limiting the pressure to about 28,000 pounds per square inch, as the highest safe limit for cast iron, the muzzle velocity for an 800-pound projectile will probably not average above 1,750 feet even with the exercise of the greatest care in the manufacture of the powder. The total energy thus imparted to the projectile is about the same as would be obtained from a full power 10½-inch steel rifle, the weight of which is 21.5 tons less than that of this 12-inch cast-iron gun.

At the 50th round erosions were observed in the bore, which increased in number and in gravity of character as the firing progressed. At the 137th round the erosion had become so pronounced along the front slope of the powder chamber and in the shot recess that the Board decided to discontinue the firing, believing the gun to be unsafe (Appendix 10). It is thought that by means of a lining tube, inserted either at the outset or after the bore has begun to suffer from erosion, the life-time of such a gun would be prolonged; but the Department has now partly completed a 12-inch cast iron gun, to be lined with a steel tube, and it is thought expedient to await its trial before lining the present 12-inch gun. It is well understood that erosion of the bore is one of the chief sources of deterioration in modern guns firing heavy charges, and that its action is so energetic that a renewing, by some means, of the surface of the bore is necessitated after a comparatively small number of rounds have been fired. The larger the powder charge and the higher the pressures exerted by the gases, the more aggravated will be the effects from erosion; while, on the other hand, those effects will be diminished as the bore is straight, or free from slopes or shoulders that obstruct the free passage of gas, and as the metal of the bore is dense, smooth and infusible. In the latter respects, steel has obvious advantages over cast iron; but there are also, great differences between different grades of steel. The erosion of the 12-inch cast-iron gun, after the 137th round, is well shown by the photographs accompanying the report of the Board. (Appendix 10.)

The trial of the 12-inch cast-iron gun, tubed with steel should furnish useful information with respect to the limit of endurance that may be attained with cast-iron guns, when thus protected against the destructive effects of erosion.

Experimental 12-inch B. L. Rifles.—Cast-iron tubed with steel; cast-iron hooped and tubed with steel.

The contracts for the manufacture of the above guns, although extended about one year in each case, were not completed by June 30, 1886, the end of the fiscal year, at which time the appropriations made under the act of March 3, 1883, and applicable to their manufacture, expired by limitation of law. Accordingly a fresh appropriation is now necessary in order to complete the guns, and a provision to that effect was made a clause of the fortifications bill at the last session of Congress, but failed, with the fortifications bill, to become a law. The present stage of progress on the guns is as follows:

The 12-inch B. L. rifle, hooped and tubed, has been assembled, and the breech mechanism is ready to be fitted, so that there remains in order to complete the gun only the finishing of bore and exterior of chase, and the rifling. The body for the 12-inch B. L. rifle, tubed, having been successfully cast at the fourth trial, is now rough bored and turned, and counter bored for receiving its tube; the tube is rough turned and the breech mechanism is in readiness to be fitted to the gun. Should Congress reconsider its action on the fortifications bill for the year 1886–'87, this coming winter, and appropriate the necessary money, it will be practicable to complete both guns within the present fiscal year.

Experimental 12-inch M. L. Rifled Mortar, cast-iron steel-hooped.

The trial of this piece has been in progress, under the supervision of the Board for Testing Rifled Cannon, &c., since July, 1885, and a progress report is contained in Appendix 11. The full charge for the mortar was fixed at 52 pounds and the weight of the charged shell 610 pounds. With full and half charges the velocity and pressures were as follows:

Kind of powder.	Charge.	Shell.	Velocity.	Pressure.
	Pounds.	*Pounds.*	*Feet.*	*Pounds.*
O. V.	52	610	908	26,880
M. V	26	610	663	11,020

The following ranges were obtained with full and half charges:

Kind of powder.	Charge.	Shell.	Elevation.	Range.		Approximate time of flight.
	Pounds.	*Pounds.*	*Degrees.*	*Yards.*	*Miles.*	*Seconds.*
M. V	26	610	60	3,366	1.91	36.0
	26	610	28	3,476	1.97	19.1
O. V	52	610	60	6,992	3.97	50.5
	52	610	28	7,252	4.1	27.5
	52	610	45	7,983	4.53	....

The computed height of trajectory, for a projectile of 610 pounds having a muzzle velocity of 1,000 feet, and fired at an elevation of 60 degrees, is 3,197 yards; angle of fall about 67 degrees, velocity at impact 787 feet, and the penetration in iron 8 inches under normal impact.

With regard to accuracy of fire, some of the targets made are excellent, fully equalling the best results attained abroad with sea-coast B. L. mortars, but there is a very considerable want of uniformity. On the other hand, it may be remarked that the published records of firings made with B. L. mortars abroad are not as full and complete as could be desired for purposes of comparison. In order therefore to determine by careful and extensive trial the relative merits, as regards accuracy of fire, of muzzle-loading and breech-loading mortars, the Department has placed under fabrication a 12-inch B. L. mortar of cast-iron, hooped with steel, similar to the present M. L. mortar, except as to such details of chambering, rifling and type of projectile as are peculiar to breech-loading systems. The body for this mortar has been cast at the South Boston Iron Works, and is nearly ready for the hoops. The hoops and forgings for breech mechanism, are being made at the Midvale Steel Works, and will soon be completed. The trials of the 12-inch M. L. mortar have also demonstrated the necessity of using a sabot made with great care and possessing the necessary degree of sensitiveness, which are certainly objectionable features for service, and which do not obtain with the breech-loading system. It is even possible that, to obtain the maximum of efficiency with M. L. mortars, sabots of different degrees of sensibility are a necessity. The target records with the 12-inch M. L. mortar are given in the report of the Board. (Appendix 11.)

With regard to endurance, the mortar has been fired thus far about 400 rounds. The star-gauging after the last round shows no material enlargement of the bore, and the piece is apparently in as good condition as ever. The construction is therefore abundantly strong. The rapidity of fire has been from 7 to 8.5 rounds per hour, which has included the placing and renewing of a loading platform at each fire,—an inconvenience that would not occur in actual service, as a permanent banquette would be provided.

The shells for the mortar are designed for use with the Hotchkiss base fuze, but no trials have as yet been made to test either the action of the fuze or the effect of explosion of the charged shell.

The endurance test of the mortar will be continued up to 500 rounds, and some further modification or form of sabot will be tried with the object of improving the accuracy of fire.

Experimental 10-inch B. L. Rifles.—Cast-iron, wire-wrapped; steel, wire-wrapped.

These guns were under manufacture at the Watertown Arsenal. The cast-iron gun is well along towards completion. There only remains to

be applied four layers of wire, after which the gun is to be finished on the outside, finished bored and rifled, and the recess for the breech block threaded. A very interesting and able progress report on the fabrication of this gun has been submitted by Lieut. William Crozier, Ordnance Department. (Appendix 25.) The work on the gun has been stopped owing to the failure of Congress, at its last session, to make the necessary appropriation for continuing it.

Progress towards completing the 10-inch wire steel gun has been slow, owing mainly to the novelty and manifold detail of the construction. This gun is still in a very backward state, that stage not having yet been reached in which the various parts are being finished for assemblage. Work has ceased on this gun also, for the same reason as the above.

Experimental 10-*inch B. L. Rifle, steel-hooped.*

The tube, jacket and trunnion hoop for this gun were ordered from Sir J. Whitworth & Co., and the hoops principally from the Cambria Iron Works, though the chase hoops, with the breech mechanism forgings are being manufactured by the Midvale Steel Company. Progress in the manufacture of hoops at the Cambria Works has been slow, but the results obtained have been very gratifying, fully conforming to the high requirements specfied in the contract; and it should be remembered that this is the first effort made by this company in the production of gun steel. The delay in completing this gun will be more directly chargeable to a failure to secure prompt delivery of suitable tube and jacket forgings.

Experimental 8-*inch B. L. Rifle, steel.*

This gun was completed the last of June, 1886, and sent to the proving ground for trial. The tube and jacket were procured from Sir J. Whitworth & Co., the hoops and the forgings for breech mechanism from the Midvale Steel Company. The gun has a total length of 21.5 feet, with 30 calibers length of bore, and weighs 13 tons; the hooping extends over the breech and part of the chase, stopping at 91 inches from the muzzle. (For description of gun and manufacture see Appendixes 17 and 18.) The proposed powder charge was 100 pounds, and the projectile 285 pounds, of 3½ calibers length, with which it was expected to realize a velocity of 1,825 feet without exceeding a pressure of 16 tons—36,000 pounds—per square inch in the powder chamber. (See Appendix 33, Report of the Chief of Ordnance, 1885.) The gun has been fired, under the supervision of the Ordnance Board, 24 rounds, the firings thus far having been mainly for the purpose of determining a suitable grade of powder and the best width of forcing band for the

projectile. Following are some representative results, using brown prismatic powder:

Ballistic results.

Kind of powder.	Weight of charge.	Projectile.	Velocity at 150 feet from muzzle.	Pressure per square inch.
	Pounds.	*Pounds.*	*Feet.*	*Pounds.*
Rottweil-Hamburg	100	182	2,185	29,450
	100	235	1,938	32,150
	100	286	1,787	32,800
Du Point's P. A	100	235	1,929	32,950
Du Point's:				
P. A	100	286	1,812	35,450
P. I	100	286	1,702	26,425
P. K	100	235	2,017	37,662

ACCURACY OF FIRE.

In firing two series of five shots each at a target 3,000 yards distant to determine which of two different forcing bands submitted for trial, was of the better width, the following results were obtained with the band adopted—

Target 30 by 40 feet—range 3,000 yards.

	Feet.
Mean vertical deviation from center of impact	1.90
Mean horizontal deviation from center of impact	1.56
Mean deviation from center of impact	2.46

or the centers of all the shot-holes were contained within a circle of 6½ feet diameter, which denotes a very high degree of accuracy.

The Du Pont brown prismatic powder has given a muzzle velocity of 1,820 feet, with a pressure of 35,450 pounds per square inch, using a charge of 100 pounds and a projectile of 286 pounds, and although this result is quite satisfactory, as compared with results obtained abroad, yet it is thought that some improvement may still be made. Some further samples have accordingly been ordered for trial. The firing of the experimental 8-inch steel rifle has enabled the Department to settle through its own experiments and with a minimum cost the recently vexed question as to whether or not the modern steel guns of this caliber should be hooped to the muzzle. The question came into prominence in Europe after the manufacture of this gun had been commenced, and was raised by the bursting of several foreign guns having no hoops over the chase. The remedy generally adopted abroad has been to hoop the gun throughout. The principal objections to this are the increased weight and cost of manufacture. In the 8-inch gun the Department possessed a tube the tests of which at the muzzle showed exceptionally fine quality of metal, and was of such dimensions as to give abundant strength for anticipated pressures. Instead then of changing the design of the gun to conform to foreign methods the Department determined to settle the question for itself. The gun was provisionally finished without the

chase hooping, sent to the proving ground and fired with heavy charges. The most careful attention has been paid to enlargements of the bore within the unhooped portion of the chase. During the firing of the twenty-four rounds the bore was star gauged after the first, fourth, seventh, thirteenth, twenty-third and twenty-fourth rounds. Even after the thirteenth round the maximum enlargement in the unhooped chase was but $\frac{2}{1000}$ of an inch. After the twenty-fourth round for about 12 inches in the length of the bore near the muzzle the enlargement was $\frac{8}{1000}$ of an inch. This enlargement is in itself small, showing an extension of only $\frac{75}{100000}$ of an inch, per linear inch, or less than one-half of one per cent. of the ultimate extensibility of the metal after rupture, as determined by tests of bars cut from the tube forging itself. A careful consideration of the results, however, led to the conclusion that the chase should be hooped to the muzzle, having also in view the purpose of the Testing Board to fire the gun to extremity. This modification in the design will permit, with a suitable powder adapted to a high density of loading, of increasing the present powder charge, if desired, and will enable the Department fully to develop the ballistic properties for guns of this class. The gun has been returned to the West Point Foundry, where it is now in the lathe being turned for its chase-hooping.* It is expected that the trial will be renewed in about two months.

This 8-inch gun is made largely of imported steel. The first forgings imported were rejected as not up to our standard of what the metal should be. The machining of the steel and fashioning of the gun, was done in this country. The technical work, such as determining the specifications, and the details of the construction, the shrinkages, &c., and the daily supervision and inspection, was the exclusive work of ordnance officers. In the manufacture of high-power steel guns such as these no rule-of-thumb methods can be followed. Scientific study, and technical skill and devoted attention to the work can alone reach successful results. The few rounds already fired prove that the work was well done, and gives us every reason to believe that the qualities of steel required for guns and the manufacture of guns can be intrusted with entire confidence to the officers of this Department.

I may here remark, that, owing to the failure of the fortifications bill, and the consequent inability of the Department to procure new supplies of powder, it would have been impracticable to test this new 8-inch gun after its completion, except for the fact that the Department had an existing contract with the Messrs. Du Pont for a supply of brown powder.

* Since writing the above the chase of the 8-inch rifle has been turned down for the reception of its hoops, and after removing the necessary metal on the exterior it was ascertained that the bore had undergone considerable restoration, which has materially reduced the above-noted enlargement. This fact points to the existence of initial strains in the original tube, due probably to faulty treatment in manufacture, and which, acting in the same direction as the powder strains, caused an enlargement of the bore such as was not to be expected from the action of the powder alone.

Production of steel gun forgings.

The Midvale Steel Company, has completed its contract for the delivery of twenty-five sets of forgings for 3.2-inch B. L. field guns. The steel furnished has been of a superior quality, exceeding the requirements of the contract. These works have also completed all the parts for the 5-inch B. L. siege gun, excepting the jacket, and that will be delivered in November. A tube and trunnion hoop for an 8-inch B. L. rifle have also been successfully forged and accepted. The production of the 8-inch rifle jacket has been attended with considerable difficulty, and a number of failures have been experienced, this being the largest gun forging thus far undertaken at Nicetown. But the last attempt has, there is reason to believe, proved entirely successful, and the manufacturers have gained in compensation for their failures most valuable practical knowledge of how to deal with large forgings, and thus have broken fresh ground in the development of the steel industry.

Prior to ordering the trunnion hoop for the 8-inch gun, as the production of a forged steel trunnion hoop—at least of any considerable size—had not hitherto been accomplished in this country, and as it was very desirable to know accurately the mechanical qualities of such a forging, the Department procured from the Midvale Steel Company, for purposes of test, a forged trunnion hoop of about the same size as that required for the 8-inch rifle. When completed this trunnion hoop was sent to the West Point Foundry, where it was cut in half along a plane passing through the axis of the trunnions and perpendicular to the axis of the hoop. One of the halves was then subjected to thorough mechanical test by means of test specimens taken from various parts along the inner face, while the other half was subjected first to an elastic, and then to a strength test by being shrunk successively on two cast-iron cylinders. The results by both methods of test were satisfactory and demonstrated the ability of the Midvale Steel Company, to cope with these difficult forgings. Following are some results obtained from the 8-inch tube and trunnion hoop. The test specimens were taken tangentially, those from the tube being 3 inches long and of .564 of an inch diameter, and those from the trunnion hoop 6 inches long and of .564 of an inch diameter:

8-INCH TUBE—TENSILE TESTS.

	Elastic limit.	Tensile strength.	Elongation after rupture.
	Pounds.	*Pounds.*	*Per cent.*
Breech end:			
Outside	51,000	90,400	20.00
Middle	46,000	86,200	21.00
Inside	49,000	86,840	23.33
Means	48,667	87,818	21.44
Muzzle end:			
Outside	52,000	94,000	19.67
Middle	50,000	91,600	21.33
Inside	53,000	94,320	17.00
Means	51,667	93,333	19.33

8-INCH EXPERIMENTAL TRUNNION HOOP—TENSILE TESTS.

	Elastic limit.	Tensile strength.	Elongation after rupture.
	Pounds.	*Pounds.*	*Per cent.*
Outer end, A:			
Minimum	49,000	89,600	17.67
Maximum	57,000	93,920	22.17
Average	53,750	91,890	19.25
Center, C:			
Minimum	45,000	80,760	16.50
Maximum	56,000	91,960	19.33
Average	48,300	86,652	17.81
Outer end, B:			
Minimum	44,000	87,000	14.50
Maximum	48,000	89,000	20.30
Average	46,250	88,090	18.04

The results from the shrinkage tests of the trunnion hoop showed that, whilst the hoop was weakest in the vicinity of the trunnions, the hoop as a whole was adapted to purposes of gun construction, yet that due care must be exercised in the determination of the shrinkage to be employed, as an excessive shrinkage would tend to develop a set in the trunnion masses when the gun is fired. A full report on this experimental trunnion hoop, showing the locations of the test specimens and describing the tests, and giving the conclusions to be drawn from them, is contained in Appendix 26. Since the manufacture of the experimental trunnion hoop the Midvale Steel Company, has delivered the 8-inch rifle forged trunnion hoop, and a similar hoop for the 12-inch B. L. mortar, the end tests of which are nearly equal to those from cylindrical hoops. For full report of the operations at these works during the past year, see Appendix 23.

At the Cambria Iron Works the Department has had a lot of twenty steel hoops under manufacture since September 15, 1885. In this, their first attempt at the production of steel-gun forgings, the Cambria Works have encountered many obstacles, particularly so as the hoops are of considerable size and the specified qualities for the metal very high. But they are steadily completing their contract and fully meeting its requirements in spite of difficulties. A good part of the hoops have been delivered, and the remainder are in a forward state of completion. This establishment has also in hand for the Department a set of forgings for a 7-inch B. L. rifled howitzer, which will give them an opportunity for acquiring experience in the production of steel tubes and forged trunnion hoops. A full report of the operations at the Cambria Works during the past year, with an exhibit of the results obtained from the 10-inch rifle hoops is given in Appendix 24.

The status of the steel works which have thus far undertaken the production of gun steel is to-day about as follows: There is *one* establishment able, with present facilities, to produce all the forgings, and of the required qualities, for a steel gun of 8 inches caliber, and hoops of all sizes except the very largest and heaviest, and the breech mechanism and smaller forgings for all calibers. There are *two* establish-

ments now able to produce the tubes and jackets and miscellaneous forgings for guns of small caliber and hoops of a very considerable size.

This represents the best that can be done to-day by the steel works of this country, and in some respects their experience is yet so new and the extent of their plant and facilities so limited that a great deal of time is requisite for the production of the forgings. The orders from the Department have also been very limited, but with the prospect of a larger demand there is but little doubt that the works with which the Department has had dealings will respond with all needed alacrity in providing the necessary facilities for promptly executing its work. It is thought that these manufacturers could commence delivering the heavier forgings, say for a 10-inch rifle, from eighteen months to two years after date of contract, but the production of such forgings would for several years be slow, as the manufacturers would wish to feel sure of their ground before assuming the risk of a number of possible rejections. The production of the tube and jacket forgings for 12-inch guns could be accomplished in from two and one-half to three years. Then the time for finishing and assembling the parts—that is the manufacturing of the gun—must be added to the above in making any estimate on the procurement of armament. In this connection I quote from my last annual report the following remarks, which are quite as much in point now as at the date when written:

Should Congress make a sufficient appropriation to enable this Department to advertise for the forgings, say for 100 of these 10-inch steel rifles, it is quite certain that some of our steel manufacturers would provide the requisite press for the production of forgings, with the oil tanks, and annealing furnaces for their treatment, in about a year; and that they would begin to deliver the rough-finished forgings within six months afterwards, or say eighteen mouths after date of contract. It is even safe to say that they should so design the new plant that it should possess sufficient capacity for the production of the forgings required for 12-inch steel guns; thus in the near future would our own steel makers be placed on a footing to supply the forgings for guns of a power far in excess of anything we can hope to obtain from the use of cast iron alone. Liberal appropriations by Congress, to extend over a number of years, for the manufacture of 8, 10, and 12 inch steel rifles, and ultimately of 16-inch and higher calibers, would, it is believed, prove the truest policy for the development of our own resources, and the *surest* for placing our extended coast in a proper state of defense.

With regard to the best method of developing our steel manufacture, the opinion of the House Commission on Ordnance and Gunnery, of which Hon. S. J. Randall was chairman, as expressed in their report submitted last session, was as follows:

It would be more in the line of prudence, economy and efficiency in the guns we are to obtain, to proceed carefully to make smaller guns, and work up gradually to the larger ones, than to suddenly appropriate for the latter before we even know that the smaller can be made; and the commission have no hesitation in recommending that all guns for use by the Army and Navy, including those for fortifications, when constructed, should be constructed in the United States.

The question of making gun steel even in small masses, is a delicate and difficult operation. It therefore seems that the best course to pursue is to confine ourselves at present to guns of from 8 to 12 inch caliber.

By this means workmen, foremen, corporations, and ordnance officers will be educated, and a body of data accumulated that ought to result in improved and more economical processes, and enable them to construct larger guns, which will not only be more efficient, but will remove the element of uncertainty from the question of what is sufficient remuneration.

Such a policy of development, as above indicated, is believed to be a sound one. It is considered a mistake to expect steel makers to put up at the outset the plant and facilities requisite for the manufacture of the very largest forgings, such for instance as those used in the construction of 100-ton guns. The requisite machinery for the production of even the smaller forgings will be to a considerable extent *experimental* with our manufacturers, and must be gradually developed, along with our types of guns, until the experience acquired in the manufacture of the smaller forgings, as 8-inch, 10-inch, and 12-inch, shall clearly indicate the best methods to be pursued in producing the largest forgings. Such gradual development will prove sure and economical, and the *ultimatum*—the production of the forgings for 100-ton guns—will be attained quite as speedily, and with more certainty and satisfaction, than by the scheme of a sudden and enormous expansion of their manufacturing facilities.

Sea-coast carriages.

The work at Watertown Arsenal during the past year on alterations of carriages has been confined to the carriages adopted for the 8-inch M. L. rifle, converted. Some 50 barbette and casemate 10-inch smoothbore gun-carriages have been altered and issued to various forts and about 20 more have been partly completed, whilst a considerable quantity of material had been procured, with the object of continuing this work during thecoming year. But this work has been interrupted through failure of the fortifications bill, and cannot be resumed until an appropriation is available therefor. The discontinuance of this most necessary work is to be deplored, as it prevents the mounting and placing in a serviceable condition of the existing armament of the country, which however feeble it may be in comparison with the armaments that might be brought against us, it is yet our duty to make the most of until something better is provided.

The Board on Fortifications or other Defenses considered that three types of carriages would be required for mounting sea-coast guns, viz, for turrets and casemates, muzzle-pivoting or minimum embrasure carriages; for barbettes on low and exposed sites, disappearing carriages, and for barbettes on high sites, some modification of our present type of barbette carriage. It is the intention of the Department, whenever it shall have requisite funds at its disposal to procure carriages of the above types for test, in order to determine suitable designs for adoption. Of the disappearing type of carriage, several promising designs have been originated in this country as the Buffington, King and

Brewer; and the King carriage has been subjected to very satisfactory test with the 15-inch smooth-bore gun. In addition to one or more of these, it might be well to test in comparison with them a hydro-pneumatic disappearing carriage on the general plan of that recently brought out in England, and which has given very satisfactory results. Disappearing carriages will be required for 10 and 12 inch rifles, and the proposed experimental carriages would be adapted to the smaller, or 10-inch gun, as guns of that caliber would be earliest available for trial. For high barbettes a carriage similar in general features to the Vavasseur, which is compact and readily handled by manual power, would probably prove most effective and economical. With this carriage the gun would be surmounted by a steel hood, to furnish additional protection to the gunners. This type of carriage could also be readily adapted, it is thought, to hydraulic lifts, should they be introduced into our fortifications. After the manufacture and trial of the carriages named, the next step would be the development of turret and casemate carriages, which are more complicated and expensive constructions, and which will require—probably casemate as well as turret—the introduction of steam power, in connection with hydraulic machinery, or machinery adapted to the use of compressed air, for readily maneuvering the guns.

This question of gun-carriages—a difficult one even when considered with reference solely to maneuvering and controlling the recoil of the gun—requires especial study and very carefully drawn conclusions when considered with reference to the peculiar conditions of our service. We have a very extended coast line, with many points at which defenses must be provided, and yet so small is our artillery force, in peace times, that at most points the carriages may stand idle for years, or at least may not receive that attention and care which are indispensable to their preservation, if involving in their construction complicated and nicely adjusted machinery. Hence, always keeping in view the requisite degree of efficiency, simplicity of construction should be the prime consideration, even if obtained at the sacrifice of some facility of handling and maneuvering. But the absolute degree of efficiency, desirable or attainable, at any particular point will of course depend on local conditions. At our principal forts there will always be a sufficient garrison to take care of the armament, and for metallic defenses, as casemates and turrets, to economize space and attain the maximum efficiency, carriages involving considerable mechanism in their construction will unquestionably be required.

Powlett Pneumatic Gun Carriage.

The Powlett 12-inch rifle gun carriage, constructed under the provisions of the act of March 3, 1885, has been partially tested during the year, in connection with the trial of the 12-inch B. L. rifle, cast iron. The carriage is operated by means of compressed air, supplied from an

accumulator in connection with a condensing engine. One hundred and four rounds have been fired from the 12-inch B. L. rifle since it has been mounted on the Powlett carriage. The Ordnance Board has submitted a progress report on the test of the carriage, (Appendix 12) and expresses the opinion; that the Powlett pneumatic carriage can be accurately and quickly traversed by means of the worm gearing, and can be laid in any desired line rapidly enough for the purposes of the land service; that the gun can be elevated and depressed with accuracy but it takes as long, if not longer, than when done by hand, and in the excitement of action the slight motions needed to fix it at the desired angle are difficult to accomplish. The Board objects to the complicated arrangement of supply pipes, branches and valves, and deems it vital that they be greatly simplified; and considers the apparatus for checking recoil too complicated, and inferior to the ordinary hydraulic buffer.

The Board does not believe that the use of compressed air for maneuvering sea-coast artillery has been sufficiently tried to justify the expression of an opinion, but admits that it possesses certain advantages that make its investigation very important. The carriage has been materially improved since it was first presented, and doubtless its construction can with greater experience be simplified and strengthened, but the Board recommends that further expenditure by this Department be suspended until the trial of the carriage ordered by the Navy Department has been completed and the results known.

As this is the first carriage made and tried, the results are deemed favorable, and, with further simplification of details, as indicated by the experience already had, the trial of new constructions for sea-coast purposes would justify the expense.

Flank Defense Torpedo Lines.

The Ordnance Board has submitted a progress report on the experiments being made for developing an effective system of defense for torpedo lines. The report is voluminous, and the progress made is encouraging, but for prudential reasons it is not deemed expedient to make public the report.

Breech-closing Devices.

The trial of the Yates' breech mechanism was completed this year under the supervision of the Board for Testing Rifled Cannon, &c. The mechanism had been applied to a 10-inch Rodman smooth-bore gun, after converting it into an 8-inch rifle by lining with a steel tube. (Appendix 9.) The gun has been fired with charges of 35 pounds of powder and a projectile of 181 pounds, the same as employed with the service 8-inch M. L. rifle, converted, and with the accompaniment of about the same pressures. At the 312th round the gun burst explosively, and as the device had not proved satisfactory to the Board, it was not favorably recommended. (Appendix 9.)

Obturating Primers.

The trial of obturating primers for cannon has been continued this year, and a satisfactory primer, both friction and electric, has been obtained. The primer with an interrupted screw head was found to answer well for large guns, but its size precludes its use with small calibers. Accordingly a new primer of smaller dimensions with a full screw on the head was tried and with satisfactory results, using either brass or steel for the body of the primer. A description of the primers is contained in Appendix 28.

Tests of Frictional Resistance due to Shrinkage.

The Department has completed a very interesting series of experiments this year at the Watertown Arsenal, having for their object the determination of the resistance offered by friction, due to shrinkage, to longitudinal movement between the surfaces of contact of cylinders, as well as the ratio which such resistance bears to the normal pressure exerted by the shrinkage. Two sections of an 8-inch gun hoop, having the same diameters but being of different lengths, were first shrunk on steel cylinders with the same shrinkage. The hoops were then pushed off by pressure applied by means of the testing machine. A second set of hoops was then assembled under an equal, but considerably higher shrinkage, and the operation of removal by the testing machine repeated. From the data derived from these experiments some useful practical deductions have been made touching the longitudinal assistance to be derived from hoops, &c., and the efficacy of the grip, due to shrinkage, exerted on an inner tube by its enveloping jacket, hooped or otherwise, to prevent separation in firing. The completed report on these experiments is not in readiness to be incorporated in this annual report but is in course of preparation for early publication.

STEEL SIEGE GUNS.—*Experimental 5-inch B. L. Rifle.*

Work has progressed on this gun during the year, at Watertown Arsenal. All the forgings, except the jacket, have been delivered. In the production of the forging for the jacket there has been unusual and unexpected delay, for its size is such as to bring it easily within the manufacturing facilities of the Midvale Steel Company. Several attempts, however, proved failures, but it is now expected that a satisfactory forging will be delivered not later than November. A carriage has been designed for this gun by Capt. Charles Shaler, Ordnance Department, which is being constructed at the Springfield Armory under the supervision of Colonel Buffington.

Experimental 7-inch B. L. R. Howitzer.

This piece was designed by the Ordnance Board, (Appendix 14), and a contract was made with the Cambria Iron Works for furnishing all

the forgings required for its construction. The qualities specified for this steel were the same as for the 5-inch siege rifle, viz:

	Tube	Jacket.	Trunnion-hoop.
Elastic limit.....pounds..	42,000	52,000	48,000
Tensile strength.....do....	88,000	95,000	95,000
Elongation after rupture.....per cent..	20	18	15

STEEL FIELD GUNS.

After the satisfactory results obtained with the experimental steel 3.2-inch B. L. rifle, the Department, last year, contracted with the Midvale Steel Company for the delivery of complete sets of forgings for twenty-five similar guns. Five of the guns were placed under manufacture at the Watertown Arsenal, and the remainder were awarded to the West Point Foundry Association, they being the lowest bidders for the work. It was expected that these guns would be completed by the early spring, but delay in the delivery of the forgings has occasioned a like delay in completing the guns. A number of the guns are, however, already finished, and it is expected that the whole lot will be completed by the end of November. The experimental metal field carriage made for these 3.2-inch guns failed on trial, owing, it is believed, in part to defective metal, and in part to some defect in workmanship, or to structural weakness. A new carriage is, however, about completed, and will be subjected to trial as soon as received at the Proving Ground.*

FIELD GUN CARRIAGES.

The Department in its annual estimates for this year, has asked for a liberal appropriation for the construction of field gun carriages. It has on hand about 500 serviceable 3-inch wrought iron M. L. rifles, and has also to provide carriages for the new steel guns. The old wooden car-

* Since writing the above the new field carriage has been received at the Proving Ground and subjected to a most satisfactory test. The carriage is of simple, not compound construction, and is made of mild steel,—the cheek plates being double, with curved flanges above and below. It is fitted with the spring brakes for checking recoil and the flanged axle for securing stiffness that have been already successfully tested in a previous carriage. The new carriage weighs only 1,300 pounds, and is graceful in its outlines. It was tested by firing 500 rounds from the 3.2-inch steel field gun, of less than 800 pounds weight, using charges of 3¾ pounds, with a projectile of 13 pounds, having a velocity of over 1,700 feet. During the firing, the carriage rested on elastic planks, in heavy sand, and various angles of elevation up to the maximum were used, and charges that gave over 35,000 pounds pressure per square inch of chamber, and it has come out of this severe ordeal in almost perfect condition.

This carriage, with its accessories, was designed by Lieut. Col. Buffington, of the Ordnance Department, and the Department has now placed the manufacture of the 25 carriages for issue with the new steel field guns, in Colonel Buffington's hands, at the National Armory.

riages, made years since for the wrought iron guns, have so deteriorated, notwithstanding the repairs made upon them from time to time, that at present it may be said that we have no serviceable carriages for issue with those guns. The metal carriages designed for the new steel guns will serve for the wrought iron guns as well, and the wrought iron can be replaced by the steel guns as the manufacture of the latter progresses. An alternative policy would be the reconstruction of a number of wooden carriages but such carriages would be useless for the service of the new guns, and would become obsolete so soon as the old guns were replaced by the new. The needs of the service in respect to a supply of carriages for the field artillery are most pressing and the appropriation asked for is earnestly recommended.

PACKING OUTFIT FOR HOTCHKISS MOUNTAIN GUN.

The packing of the Hotchkiss mountain gun, carriage and ammunition was made the subject of careful study and experiment during the year 1885 by Lieutenant Colonel Flagler, Ordnance Department. Colonel Flagler having submitted the results of his investigations, with detailed drawings of his proposed outfit, in a report to this Office (Appendix 31) the Department directed the manufacture of ten complete sets for issue to troops and practical trial in the field.

The salient features of Colonel Flagler's outfit are: a permanent pack saddle instead of an *aparejo;* the substitution, for the heavy ungainly shafts used in single draft, of a light pole splinter-bar, pole, yoke and breast harness, for double draft, which are readily packed, weigh 30 pounds less than the shafts and shaft harness, and do not entail any addition to the number of draft animals now required; packing the ammunition in a number of small boxes, convenient for the supply of ammunition and for packing, and sufficiently cheap to admit of their being thrown away after being emptied. It is believed that this outfit, if it does not prove an entirely satisfactory solution of a somewhat vexing problem, will at least largely clear the way towards such solution.

RUSSELL'S HYDRAULIC BUFFERS.

Capt. A. H. Russell, Ordnance Department, has submitted a brief history of the hydraulic buffer, with valved piston-head, for overcoming recoil of guns, invented by him. (Appendix 33.) Captain Russell claims that this buffer is identical in principle with that patented in this country as well as in England, some years subsequent to the appearance of his invention, by J. Vavasseur, and that therefore the latter has no valid claim against the United States for the use of the Vavasseur system, so far as it is covered by the Russell invention. Captain Russell has no pecuniary interest in the question, but simply desires to secure professional recognition for his invention and immunity to the Government in using the Vavasseur patent.

I have the honor to submit the following papers, heretofore referred to:

Appendix 1.—Statement of principal articles procured by fabrication during the year ended June 30, 1886.

Appendix 2.—Statement of principal articles procured by purchase during the year ended June 30, 1886.

Appendix 3.—Statement of ordnance, ordnance stores, &c., issued to the military establishment, including the national homes for soldiers of the volunteer and regular Army, and exclusive of the militia during the year ended June 30, 1886.

Appendix 4.—Apportionment for the fiscal year ending June 30, 1887, of the annual appropriation of $200,000 for arming and equipping the militia, under sections 1661 and 1667, Revised Statutes.

Appendix 5.—Statement of ordnance, ordnance stores, &c., distributed to the militia from July 1, 1885, to June 30, 1886, under section 1667, Revised Statutes.

Appendix 6.—Statement of arms, ammunition, &c., distributed to the Territories and States bordering thereon, from July 1, 1885, to June 30, 1886, under the joint resolutions of July 3, 1876, March 3, 1877, and June 7, 1878, and the act of May 16, 1878.

Appendix 7.—Statement of ordnance, ordnance stores, &c., distributed to colleges from July 1, 1885, to June 30, 1886, under section 1225, Revised Statutes.

Appendix 8.—Showing the stations and duties of the officers of the Ordnance Department.

REPORTS OF THE BOARD FOR TESTING RIFLED CANNON, ETC., APPOINTED UNDER THE ACT OF JULY 5, 1884.

Appendix 9.—Report on Yates B. L. rifle. (5 plates.)

Appendix 10.—Progress report on trial of 12-inch B. L. rifle, cast iron. (1 plate.)

Appendix 11.—Progress report on trial of 12-inch M. L. rifled mortar.

REPORTS OF THE ORDNANCE BOARD.

Appendix 12.—Powlett pneumatic gun carriage. (1 plate.)

Appendix 13.—Trial of 8-inch banded projectiles, experimental. (7 plates.)

Appendix 14.—Design for 7-inch siege howitzer. (2 plates.)

Appendix 15.—Experiments with blasting gelatine. (1 plate.)

Appendix 16.—Trial of steel and wooden ammunition chests. (6 plates.)

CONSTRUCTION OF ORDNANCE.

Appendix 17.—Construction report of 8-inch B. L. rifle, steel.

Appendix 18.—Inspection report of 8-inch B. L. rifle, steel.

Appendix 19.—Construction report of 8-inch Yates B. L. rifle.

Appendix 20.—Construction report of 8 and 10 inch proof carriage. (4 plates.)

Appendix 21.—Manufacture of 12-inch projectiles. (1 plate.)

Appendix 22.—Annual report of Inspector of Ordnance, South Boston Iron Works. (9 plates.)

Appendix 23.—Annual report of Inspector of Ordnance at Midvale Steel Works.

Appendix 24.—Annual report of Inspector of Ordnance at Cambria Iron Works.

Appendix 25.—Progress report on construction of 10-inch B. L. rifle, cast iron, wire wound. (3 plates.)

Appendix 26.—Report on an experimental forged trunnion hoop.

Appendix 27.—Report on longitudinal strength of steel gun hoops. (1 plate.)

Appendix 28.—Report on obturating friction and electric primers. (1 plate.)

Appendix 29.—Progress report on powders.

Appendix 30.—Report on fabrication of 3.2-inch steel field guns at Watertown Arsenal.

MISCELLANEOUS.

Appendix 31.—Report on packing outfit for Hotchkiss mountain gun. (17 plates.)

Appendix 32.—Report of principal operations at Cheyenne Ordnance Depot during year ending June 30, 1886.

Appendix 33.—Russell's hydraulic buffer. (2 plates.)

Appendix 34.—Report of trials of carbine cartridges.

Appendix 35.—Summary of reports on magazine guns issued for trial in service, &c.

I have the honor to be, very respectfully, your obedient servant,

S. V. BENÉT,

Brigadier-General, Chief of Ordnance.

To the honorable SECRETARY OF WAR.

APPENDIX 1.

Statement of principal articles procured by fabrication during the fiscal year ended June 30, 1886.

CLASS I.

2 breech-loading steel guns, caliber 3.2 inch.

CLASS II.

30 carriages for 6-pounder gun.
20 carriages and limbers for Gatling gun, caliber .45″.
1 carriage for 3.2-inch field gun.
1 limber for machine gun carriage, caliber .45″.
11 15-inch carriages and chassis, hydraulic cylinder, model 1883.
21 8-inch carriages and chassis, F. P. barbette hydraulic cylinder.
28 8-inch carriages and chassis, casemate, hydraulic cylinder.

CLASS III.

52 breech sights for 8-inch rifles.
10 buckets, sponge.
16 buckets, water.
20 bars, maneuvering.
9 elevating bars.
3 elevating arcs and indices.
20 fuze blocks.
4 fuze plug wrenches.
4 fuze wrenches.
11 fuze gauges.
7 gunners' gimlets.
50 gunners' haversacks.
38 gun covers, Gatling gun.
20 gun mounts, Gatling gun.
134 handspikes.
4 sets artillery harness, 2 horses, wheel.
3 sets artillery harness, 2 horses, lead.
6 sets harness, Laidley cavalry forge.
100 harness sacks.
1 set harness, 1 horse, cannonier.
1 muzzle or front sight, 12-pounder gun.
52 muzzle or front sights, 8-inch rifle.
3 pinch bars.

27 priming wires.
2 pendulum hausses.
1 rammer and staff, 3.2-inch gun.
4 rammers and staves. 11-inch rifle.
3 shell hooks.
100 securing stakes.
24 pointing stakes.
15 sight cases, Gatling.
12 sponge covers, 3-inch rifle.
2 sponge covers, 3.2-inch rifle.
10 sponge covers, 12-pounder gun.
2 sponge covers, 12-pounder mountain howitzer.
4 sponge covers, 6-pounder gun.
1 sponge and rammer, 3.2-inch rifle.
11 sponges and rammers, 12-pounder mountain howitzer.
11 sponges and rammers, 6 pounder gun.
18 sponges and rammers, 12-pounder gun.
97 sponges and rammers, 3-inch rifled gun.
4 sponges and staves, Hotchkiss mountain gun.
1 sponge and staff, 6-pounder gun.
26 tompions, 3-inch rifle.
8 tompions, 10-inch rifle.
4 tompions, 15-inch rifle.
1 tompion, 12-pounder mountain howitzer.
4 tompions, 4.5-inch rifle.
2 tompions, 11-inch rifle.
2 tompions, 13-inch gun.
1 tompion, 20-inch gun.
104 vent covers.
26 vent punches.
79 vent pieces.
6 wipers for mortars.
7 vent covers, heavy guns.
1 worm and staff, 12-pounder mountain howitzer.
1 worm and staff, 11-inch rifle.
9 pendulum hausse pouches.
24 feed guides, Gatling gun.
12 hoppers, Gatling gun.

CLASS IV.

1,000 4.2-inch Eureka shot.
50 8-inch cored shot.
132 3.2-inch steel shrapnel.
5,000 3.2-inch shell.

CLASS V.

6 canister, 8-inch choke.
113 12-pounder shot, fixed.

CLASS VI.

5,000 Springfield carbines, caliber .45", model 1884.
1,000 Springfield carbines, caliber .45", 2.4-inch barrel.
32,524 Springfield rifles, caliber .45", model 1884.

1,003	Springfield rifles, caliber .45″, rod bayonet.
2	officers' swords.
154	cavalry and field officers' sabers.
50	light artillery officers' sabers.

Class VII.

ARTILLERY ACCOUTERMENTS.

50	knapsacks for light batteries.

CAVALRY ACCOUTERMENTS.

3,066	carbine slings.
101	carbine sling swivels.
4,500	pistol holsters.
2	saber belts.
1,002	saber-belt plates.
402	saber knots.

INFANTRY EQUIPMENTS.

10,163	bayonet-scabbard bodies.
10,299	bayonet scabbards.
7,100	blanket bags.
5,720	blanket bag shoulder-straps, pairs.
10,686	cartridge boxes, pattern 1874, McKeever.
355	cartridge-belt plates.
13,175	canteens.
920	canteen straps.
6,551	coat straps, pairs.
52	frogs, sliding.
6,897	gun-slings.
5,351	haversacks.
351	haversack-straps.
5,000	tin cups.
1,114	waist belts.
1,184	waist-belt plates.
500	sword belts, leather, officers'.
1,444	gun slings, lengthened.
15,561	waist belts and plates (plates without loop).
1	waist belt and plate, N. C. O.
1,000	meat cans.
22	frogs, N. C. O. and musicians' swords.
1,059	waist-belt plates, pattern 1874.
1,000	waist belts, pattern 1874.

APPENDAGES.

26	bullet molds.
33,221	headless shell extractors.
3,078	screw-drivers.
37,650	wiping rods, wooden, rifle and carbine.
7,873	front sight covers.
417	front sight cover screws.
4,540	pistol-grips, metallic.
335	pistol-grip screws.

HORSE EQUIPMENTS.

50	bits, curb, cavalry.
1,000	bridles, curb, cavalry.
3	bridles, watering.
225	cinchas or hair girths.
5,000	horse brushes.
2,500	horse covers.
3	lariats.
203	links.
2,340	nose-bags.
3,000	picket-pins.
6	saddles.
203	saddle-bags, leather.
203	side lines.
6,899	carbine boots and straps.
51	saddle cloths, hair.
7	saddle cloths for line officers.
2,100	spur straps.
445	surcingles.

CLASS VIII.

AMMUNITION.

28,951	cartridge bags, 3-inch rifle.
120	cartridge bags, 3.2-inch rifle.
10,281	cartridge bags, 6-pounder gun.
8,028	cartridge bags, ½-pound blank.
1,230	cartridge bags, 1 pound blank.
1,000	cartridge bags, 2 pound blank.
6,000	cartridge bags, 12-pounder mountain howitzer.
27,048	cartridge bags, 12-pounder gun, light.
100	cartridge bags, 12-pounder gun, heavy.

METALLIC CARTRIDGES.

3,168,608	rifle ball cartridges, caliber .45″, reloading, model 1881.
1,209,325	rifle and carbine blank cartridges, caliber .45″, reloading, model 1882.
1,915,052	carbine ball cartridges, caliber .45″, reloading, model 1882.
613,735	revolver ball cartridges, caliber .45″, reloading, model 1882.

FUZES.

145	fuzes, metallic, time, 3.2-inch projectile.
100	fuzes, Hotchkiss base.

LEAD BALLS.

3,029,000	carbine bullets, caliber .45″, 405 grains.
9,634,100	rifle bullets, caliber .45″, 500 grains.
1,976,200	round balls, caliber .45″.
692,500	revolver bullets, caliber .45″.

MISCELLANEOUS ARTICLES.

373,700 friction primers for cannon.
10 electric primers for cannon.
23 friction primers, obturating.

CLASS IX.

MACHINES AND MISCELLANEOUS ARTICLES FOR ARTILLERY.

276 blocks.
16 blocks, half.
16 blocks, quarter.
1 capstan.
12 chocks, gun.
44 chocks, roller.
20 chocks, wheel.
1 collar, gun.
22 rollers, long.
16 rollers, short.
21 shifting planks.
24 skids.
1 sling cart, large.
1 shear, gun.
2 trunnion rings.
30 way planks.
4 platforms for mortars.
30 intrenching tools.
3 poles, 10-foot.
500 muzzle plugs, for rifles.
10 pinch bars, iron.
100 broad-sword blades, wood.
1 gin fall.
1 gin, field and siege, "Piper."
426 marking outfits.
15,498 marksmen's buttons.
8,000 marksmen's pins.
2,500 sharpshooters' badges.

RELOADING-TOOLS.

66 tools, bench, reloading, sets.
154 chargers.
50 extractors, primers.
352 dies, reloading.
160 priming tools.
320 punches, reloading.
265 punches, resizing.
100 anvils, combination.
494 dies, resizing.
100 funnels.
234 shell scrapers.
100 wiping rods.
2,000 pins, priming tool.
109 dies, resizing, bench.
1 tool, reloading, "Morse."

1 tool, resizing, "Morse."
1 die, crimping, bench.
53,580 centers for paper targets.
150 disks.
23,812,750 pasters.
514 signal flags.
949 shot-marks and staves.
248 streamers for rifle-range.
50 targets, Brinton.
73 targets, Cushing.
309. targets, Laidley revolving.
113,100 targets, paper elliptical.
24 targets, Texas.
1,881 target frames.
68 marking rods, disks, and brushes, sets.

Class X.

PARTS APPERTAINING TO CLASS I.

48 eccentric trunnion rings, 8-inch rifle.

PARTS APPERTAINING TO CLASS II.

1 ammunition chest.
243 parts of field carriage.
9 parts of Laidley cavalry forge.
8 poles for field or siege carriage.
4 pole yokes.
25 pole-prop bolts.
14 straps for ammunition chest.
6 keys and stay pins for ammunition chest.
4 pole lifts.
12 axle bodies.
30 guide hooks, bolts, and nuts, 8-inch rifle.

WHEELS.

100 fellies.
4 naves.
50 spokes.

BRIDLES AND COMPONENT PARTS.

8 bits.
5 collars.
4 leg guards.
15 hooks for tar buckets.
12 saddle seats, leather.
21 retraction ropes.
4 traces.

RAMMER HEADS.

58 rammer heads, 3-inch gun.

SPONGE HEADS.

5 sponge heads, 3-inch rifled gun.
1 sponge head, 3.2-inch rifled gun.

SPONGES.

75	sponges, 3-inch rifled gun.
6	sponges, 12-pounder gun.
40	sponges, 12-pounder mountain howitzer.
40	sabots, 12-pounder shell.
40	tin straps.
6	tips, brass, for 3.2-inch shrapnel.
300	copper bands, 3.2-inch shell.

PARTS APPERTAINING TO CLASS VI.

Parts of Springfield rifle and carbine.

1,715	stocks (wood part).
50	tips.
252	tip screws.
16	ramrod stops.
12	band springs.
106	side-screw washers.
13	butt plates.
20	butt-plate screws.
5	cover-friction springs.
201	guard bows.
77	guard-bow swivels.
185	guard-bow swivel screws.
10	guards, complete.
6,339	triggers.
1,602	trigger screws.
366	guard screws.
6	rear-sight base springs.
102	rear-sight screws.
150	rear-sight leaves.
56	leaf-slide binding screws.
48	rear-sight slide screws.
56	windage screws.
470	rear-sight joint pins
2	barrels.
2	receivers.
3,405	extractors.
571	hinge pins.
3,985	ejector springs.
3,810	ejector-spring spindles.
212	ejector studs.
60	cam latches.
260	breech-block caps.
50	thumb pieces.
5	breech blocks.
1,306	breech-block cap screws.
10,599	firing pins.
2,312	firing-pin screws.
2,441	cam-latch springs.
7	breech screws.
1,223	front sights.
727	front-sight rivets.
861	tang screws.

25	bands, upper.
629	bands, lower.
20	lock plates.
1,432	main springs.
863	main-spring swivels.
788	main-spring swivel rivets.
133	hammers.
4,070	tumblers.
1,880	tumbler screws.
2,057	bridles.
1,569	bridle screws.
3,743	sears.
2,029	sear screws.
1,983	sear springs.
899	sear-spring screws.
315	side screws.
239	ramrods.
6,000	ramrods, jointed.
359	bayonets.
165	bayonet-clasps.
415	bayonet-clasp screws.
10	bayonet-clasp stop screws.
100	swivel-bar rings.
18	locks, complete.
296	rear sights, complete.
104	stocks, assembled.
5	stocks, complete.
1	scabbard, cavalry officer's saber.
6	locking spring, Springfield rod-bayonet rifle.
30	stocks assembled, Springfield rod-bayonet rifle.
112	stocks, Hotchkiss navy rifle.
3	stocks (wood part), Springfield shotgun.
173	extractors, Springfield shotgun.

PARTS APPERTAINING TO CLASS VII.

Parts of infantry and cavalry accouterments and equipments.

10,000	buckles, bar, brass, ⅝-inch.
17,972	buckles, bar, brass, ¾-inch.
15,000	buckles, bar, brass, ⅞-inch.
5,000	buckles, wire, brass, ¾-inch.
1	button and hook for officer's sword belt.
3,000	snaps, brass, for saber belts.
1,000	hasps for saber belt plates.
10,938	saber straps.
1,268	saber attachments.

Parts of horse equipments.

839	cincha straps.
25	curb straps.
2,304	foot staples, brass.
188	girth straps.
6,900	halter straps.
65	head stalls for bridles.

1,000	hooks, snap.
1,015	halters.
792	coat straps for saddles.
3,027	rings, brass, 1¼-inch.
72	rings, iron, 2¼-inch.
329	safety straps.
10	spring snaps.
3	stirrups with guidon socket.
3,761½	stirrups with hoods, pairs.
200	stirrup hoods.

PARTS APPERTAINING TO CLASS VIII.

515	cartridge bags, empty, ½-pound.
15,454	cartridge bags, empty, 3-inch gun.
644	cartridge bags, empty, 3.2-inch rifle.
2,700	cartridge bags, empty, 6-pounder gun.
1,250	cartridge bags, empty, 4½-inch siege gun.
29,025	cartridge bags, empty, 12 pounder gun.
952	cartridge bags, empty, 8-inch converted rifle.
1,059	cartridge bags, empty, 10-inch Rodman gun.
350	cartridge bags, empty, 12-inch breech-loading rifle.
300	cartridge bags, empty, 12-inch muzzle-loading mortar.
172	cartridge bags, empty, 11-inch muzzle loading chambered gun.
4,501,000	carbine cartridge wads.
26,809,300	cartridge primers.
5,500	cartridge shells, rifle.
40,000	cartridge shells, revolver.
200	cartridge shells, rifle, "Morse."

PARTS APPERTAINING TO CLASS IX.

334	parts of targets.
1,902	parts of Laidley revolving targets.
259	parts of Cushing target.
306	frames for Laidley revolving targets.
6,000	steel frames for skirmish targets.
9,000	cloths for skirmish targets.
63,881	paper skirmish targets.
190,000	strings for skirmish targets.
1	uncapping bolt, reloading tool.
50	gauges, total length.
50	setters, primer, bench.
50	tools, reloading and crimping, bench.
50	tools, resizing, bench.
4	eccentric axles for mortar bed.
68,786	paper silhouettes.
10,500	cloth silhouettes.
200	cast-iron plates for gallery practice.
1	leg for Laidley gun lift.
500	silver bars for sharpshooters' badges.
20	base spreaders, Morse.
20	base punches, Morse.
20	extracting cups, Morse.
20	shell scrapers, Morse.

MATERIALS AND TOOLS.

MISCELLANEOUS.

1,437	arm chests.
4,110	boxes, packing.
4	boxes, packing, tin.
949	cans, tin.
332	cases.
4	bags for saddlers' and smiths' tools.
3	measures, tin.
135	buckets, tin or iron.
176	boxes, reloading tools.
7	cases, field, for shotgun outfit.

TOOLS.

46	aprons, smiths'.
414	brushes.
113	bits, assorted.
250	boxes, blacking for leather.
2	gallons browning mixture.
1	calipers.
404	chisels, various.
300	chamois-skin cases for swords.
658	dies, various.
1,218	drills.
515	brushes, paint.
2	crusher gauge plugs.
50	boxes of cleaning material.
120	clinching irons.
1	bushing obturating primer.
1,301	files, assorted.
279	files, rotary.
1	fuze-tool, Hotchkiss base.
59	gauges.
175	grease, wheel, pounds.
3	gauges, ring for setting star gauge.
1	star-gauge point.
175	hammers.
6	horses, saddlers'.
450	handles, various.
50	inspecting mirrors.
320	ingredients for leather blacking, boxes.
4	knives, shoeing.
20	knives for draw gauge.
155	gallons lacker
1	machine, lead-bar rolling.
1	machine for stamping.
1,842	mills, armorer's.
129	mandrels.
3	measuring points, star gauge, sets.
1	standard nut.
100	oil cans.
1,900	pounds harness oil.
12	oilers, tin.

155	punches, assorted.
774	pounds paint, black.
3, 675	pounds paint, olive.
1, 290	pounds paint, various.
5	pounds putty.
4	pans.
150	smiths' pokers,
2	pounds polish for leather.
307	arm-racks, portable.
287	reamers.
5	pairs magazine slippers.
5	stamps, seal.
1	stencil plate.
5, 743	parts of stoves, various.
2	scoops.
2	screens, coal.
151	shoeing boxes, leather.
124	taps, various.
668	tools for current service.
5	tools, various, for reloading tools, sets.
1	tool for Morse reloading tool, set.
1	tool for diameter caliper, set.
1	tool, resizing exp. shotgun, set.
100	tools, primer box.
100	tags, metal.
311	pounds black wax.
100	wipers, brush.
1	wheel, card.
24	creasers.
200	pincers.
150	forgings for bullet-mold gates.
20	pounds hektograph composition.
54	button sticks.
18	button brushes.
15	gallons coal tar.
150	shovels.
6	spanner belts.
2	parts of shafting.
6	cleaning plates, sheet iron.
4	castings, various.

APPENDIX 2.

Statement of principal articles procured by purchase during the fiscal year ended June 30, 1886.

CLASS I.

1	12-inch cast-iron breech-loading rifle.
1	8-inch steel breech-loading rifle.
32	8-inch muzzle-loading rifles, converted.
25	Gatling guns, 10-barrel, caliber. 45″.
10	Hotchkiss mountain guns, 42^{mm}, caliber 1″.65, with feed magazines.

CLASS II.

10	Hotchkiss steel mountain gun carriages, caliber 1″.65
1	metallic gun carriage, for 10-inch rifle.
1	Powlett pneumatic gun carriage.

CLASS III.

100	feed cases, Gatling gun, caliber .45″.
80	feed magazines, Gatling gun, caliber .45″.
50	mortar wipers.
200	paulins, 12 by 15 feet.

CLASS IV.

300	10-inch cored, cast-iron shot.
315	8-inch cored, cast-iron shot.

CLASS VI.

240	Spencer repeating shotguns.
2,000	Colt's revolvers, caliber .45.

CLASS VII.

1,002	artillery saddle blankets.
10,000	cavalry saddle blankets
12	curry-combs.
5,350	knives.
5,228	forks.
5,136	spoons.

CLASS VIII.

197,503	pounds small-arms powder.
50,000	pounds I. K. powder, for field guns.
27,700	pounds hexagonal powder.
65,575$\frac{3}{4}$	pounds brown prismatic powder.
4,000	pounds square powder.
100	pounds giant powder.
500,000	rifle-ball cartridges, caliber .50″.
132,000	rifle-ball cartridges, caliber .45″.
5,000	Hotchkiss base fuzes.
25,000	pounds drop shot.
500,000	wads.
4,100	feet safety fuze.
4	coils safety fuze.
300	caps (giant powder).
5,000	rounds Hotchkiss shell, caliber 1″.65.
1,494	rounds Hotchkiss case shot, caliber 1″.65.

CLASS IX.

12	double blocks.
13	single blocks.
1	treble block.
1	quadruple block.
2	snatch-blocks.
6	hydraulic jacks.
2	sling chains.
37	white-oak rollers.
5	differential pulleys.
12	shifting planks.
4	plane tables.

CLASS X.

5,040	bar buckles.
5,904	roller buckles.
227	pounds escutcheon pins.
1,752	rings.
4,464	spring snaps.
30,171	gun stocks.
457	parts of Colt's revolvers.
67	parts of Hotchkiss magazine rifle.
5	parts of Lee magazine rifle.
9	parts of gun carriages.
302	rubber buffers for 15-inch carriage.
1	set loading tools, Hotchkiss 42$^{m}/_{m}$ mountain gun.
632	belt hooks.
36	pointing stakes.
168	Archibald wheels for artillery carriages.

PART SECOND.

CLOTH, ROPE, ETC.

256	yards burlaps.
2,526$\frac{3}{4}$	yards cloth, oiled and enameled.

11⅜ yards cloth, woolen.
32¾ yards cloth, rubber.
74,245¼ yards cotton cloth.
845¼ yards felt.
7,336 pounds cotton waste.
8,691¼ pounds cord and twine.
12 yards canvas.
250 yards canton flannel.
300 yards flannel.
2,053 pounds hair.
15 pounds marline.
403½ yards matting.
55 mats.
50 pounds oakum.
9,784 pounds rope.
46¼ pounds sewing silk.
168 spools sewing silk.
1,100½ pounds thread.
84 spools thread.
25 yards ticking.
330 towels.
30 yards toweling.
41,151¾ yards webbing.
21 window shades.
75 yards linoleum.

FORAGE, ETC.

11,276 pounds barley.
24,095 pounds bran.
2,372 bushels corn.
31¼ barrels flour.
14 bushels grass seed.
6,774 pounds ground feed.
247,948 pounds hay.
24,500 pounds meal.
7,004¼ bushels oats.
33 barrels salt.
73,649 pounds straw.

IRONMONGERY.

681 pounds Babbitt metal.
10 bath tubs and fixtures.
305,031 pounds I and channel beams.
2 bells.
4 boilers.
10,876 bolts.
15 pounds brads.
73 papers brads.
366⅝ pounds brass, rod.
8,476¼ pounds sheet brass.
1,668 buckles, assorted.
425 pounds burrs.
58,296 buttons.
34 sets casters.

1,760¼ pounds bronze and brass castings.
109,714¾ pounds iron castings.
1,066 iron castings.
942⅓ pounds steel castings.
717½ pounds chain.
3,240 feet chain.
972 cocks, assorted.
59,988¾ pounds bar copper.
319,306¾ pounds cartridge copper.
14,059⅞ pounds sheet copper.
460 couplings.
80 door catches and fixtures.
647,488 eyelets.
921 gas burners.
796 gas fixtures, assorted.
333¼ pennyweights gold.
181½ pounds grate bars.
1,027 pairs hinges.
1,477 hooks, assorted.
11,206½ pounds horseshoes.
1,064 pounds horseshoe nails.
159 hose fittings.
7,113 pounds hoop iron.
119 $\frac{339}{2240}$ tons pig iron.
34,273¾ pounds sheet iron.
255,144 pounds wrought iron.
120 keys.
686 knobs, assorted.
3,432½ pounds lead.
1,577 locks, assorted.
63,274¾ pounds nails.
13,889 pounds nuts, assorted.
28½ pounds copper pipe.
30 feet brass pipe.
18,136 feet iron pipe.
6,809½ pounds lead pipe.
136 feet lead pipe.
574½ pounds pipe fittings.
7,130 pipe fittings, assorted.
4 pumps.
65 pulleys.
5,689 pounds rivets, assorted.
1,344½ pounds rivets and burrs.
5,905 feet metallic rope.
6,404 gross screws, assorted.
3⅜ gross screw eyes, &c.
243½ pounds German silver.
26,375⅘ pennyweights silver.
2,542⅜ pounds solder.
2,637 pounds spikes.
69½ pounds springs.
883,057 pounds bar and plate steel.
23,993 pounds steel forgings.
24,895 pounds sheet steel.
2,543,000 tacks, assorted.
441 pounds tacks, assorted.

80,763	pounds block tin.
2,612½	pounds tin foil.
151½	boxes sheet tin.
103½	pounds tubing.
1,494	pounds washers.
30	water-closets and fixtures.
15	urinals and fixtures.
11,064	pounds brass wire.
1,513½	pounds copper wire.
3,000	pounds covered copper wire.
26,723¾	pounds cartridge copper wire.
9½	pounds German silver wire.
15,777½	pounds iron wire.
55,733½	pounds steel wire.
6,468¾	pounds zinc.
2,200	tin-can screws.
691	square yards wire cloth.
2,067¾	feet wire grating and netting.
3,241	feet lightning rods.

LEATHER, ETC.

232	pounds black wax.
8,625½	feet leather belting.
141	feet rubber belting.
75	pounds buff leather.
123,924¼	square feet collar leather.
236	sides bellows leather.
2,521	sides bridle leather.
30	pounds bridle leather.
71,942	pounds harness leather.
80½	square feet bag leather.
453	pounds lace leather.
66	sides lace leather.
1,500	feet lace leather.
51½	square feet lace leather.
111	square feet trimming leather.
22	pounds polishing leather.
111	pounds sole leather.
56	sides raw-hide.
52	sheep-skins.
25	shark's skins.

LUMBER.

74,277	feet battens and strips.
718,238¾	feet boards.
432	feet joists.
15,100	laths.
594,729	feet plank.
1,619	posts and rails.
92,280	feet scantling.
142,500	shingles.
106,126	feet timber.

BUILDING MATERIALS.

20	square feet asbestos.
1,420,177	bricks.

3,501$\frac{1}{4}$ barrels cement.
648$\frac{1}{3}$ feet cement pipe.
157 barrels clay,
40 doors, wood.
1,994$\frac{3}{4}$ feet drain pipe.
19,903$\frac{72}{100}$ square feet flagging stone.
8,531$\frac{1}{3}$ feet window glass.
6,956 lights window glass.
392 cubic yards gravel.
224 pounds plastering hair.
2,005 barrels lime.
17 barrels plaster of Paris.
1,421$\frac{1}{2}$ cubic yards sand.
7,613 bushels sand.
1,936$\frac{7}{10}$ cubic feet stone.
1,560$\frac{58}{100}$ cubic yards stone.
4,065 square feet slate.
1,226 pounds tarred paper.
1,434 feet moldings.
186 rolls wall paper.
332 feet terra-cotta pipe.
8 terra-cotta traps, &c.
307 feet tiles.
16 pairs window blinds.
81 window sash.
10 window and door sills.
422 feet hair felting.
4 wrought-iron gates.

HEATING, LIGHTING, CLEANING, ETC.

50 bath bricks.
20 quarts blacking for leather.
1,288 brooms.
235 brushes, dusting, &c.
34 pounds candles.
184$\frac{125}{1000}$ square feet card-clothing.
22,175 bushels charcoal.
714 chamois skins.
3,101$\frac{1726}{2240}$ tons anthracite coal.
3,486$\frac{1930}{2240}$ tons bituminous coal.
235,669 pounds coke.
726 bushels coke.
1,690 pounds corundum.
304 corundum and emery wheels.
181$\frac{1}{2}$ reams crocus and emery cloth.
10,149 pounds emery.
25 reams emery paper.
620 pounds crocus.
18,773 fire-bricks.
292$\frac{1}{16}$ cords fire-wood.
4 grates.
12,150 pounds kaolin.
63 lanterns.
8 lamps.
198 lamp fixtures.

APPENDIX 8.

SHOWING STATIONS AND DUTIES OF THE OFFICERS OF THE ORDNANCE DEPARTMENT ON OCTOBER 1, 1886.

Rank and name.	Duty.	Address.
BRIGADIER-GENERAL.		
Stephen V. Benét	Chief of Ordnance	Washington, D. C.
COLONELS.		
1. J. McAllister, brevet	Commanding the New York Arsenal, president of the Ordnance Board, and president of Board for Testing Rifled Cannon, &c.	Governor's Island, New York City. Post-office box 1449.
2. S. Crispin, brevet	Commanding the Benicia Arsenal	Benicia, Cal.
3. T. G. Baylor, brevet	Commanding the Rock Island Arsenal.	Rock Island, Ill.
LIEUTENANT-COLONELS.		
1. J. M. Whittemore	Commanding the Watervliet Arsenal	West Troy, N. Y.
2. A. R. Buffington	Commanding the National Armory	Springfield, Mass.
3. D. W. Flagler, brevet	Commanding the Frankford Arsenal	Philadelphia, Pa.
4. A. Mordecai, brevet	Member of the Ordnance Board and member of Board for Testing Rifled Cannon, &c.	Governor's Island, New York City. Post-office box 1449.
MAJORS.		
1. F. H. Parker, brevet	Commanding the Watertown Arsenal, and member of Board for Testing Rifled Cannon, &c.	Watertown, Mass.
2. J. P. Farley	Commanding the United States Powder Depot.	Dover, N. J.
3. L. S. Babbitt	Commanding the Fort Monroe Arsenal.	Fort Monroe, Va.
4. W. A. Marye	Assistant, National Armory	Springfield, Mass.
5. I. Arnold, jr	Commanding the San Antonio Arsenal.	San Antonio, Tex.
6. C. Comly	Commanding the Indianapolis Arsenal.	Indianapolis, Ind.
7. J. R. McGinness, brevet	Assistant, Rock Island Arsenal	Rock Island, Ill.
8. G. W. McKee, brevet	Commanding the Allegheny Arsenal	Pittsburgh, Pa.
9. F. H Phipps	Commanding the Kennebec Arsenal	Augusta, Me.
10. J. W. Reilly	Commanding the Augusta Arsenal	Augusta, Ga.
CAPTAINS.		
1. J. A. Kress, brevet major	Commanding the Saint Louis Powder Depot.	Jefferson Barracks, Mo.
2. O. E. Michaelis, brevet	Assistant, Watervliet Arsenal	West Troy, N. Y.
3. C. E. Dutton	On duty under the Interior Department.	Geological Survey, Washington, D. C.
4. J. G. Butler	Assistant, National Armory	Springfield, Mass.
5. C. Bryant	Assistant, Benicia Arsenal	Benicia, Cal.
6. A. L. Varney	Assistant, Rock Island Arsenal	Rock Island, Ill.
7. J. C. Clifford	Assistant, Frankford Arsenal	Philadelphia, Pa.
8. J. E. Greer	Commanding the Fort Leavenworth Ordnance Depot, and chief ordnance officer Department of the Missouri.	Fort Leavenworth, Kans.
9. J. Pitman	Commanding the Fort Abraham Lincoln Ordnance Depot, and chief ordnance officer Department of Dakota.	Fort Abraham Lincoln, Dak.
10. C. Shaler	Member of the Ordnance Board, and member of Board for Testing Rifled Cannon, &c.	Governor's Island, New York City. Post-office box 1449.
11. H. Metcalfe	Instructor of ordnance and gunnery U. S. Military Academy.	West Point, N. Y.
12. W. S. Starring	Commanding the Cheyenne Ordnance Depot, and chief ordnance officer Department of the Platte.	Cheyenne, Wyo.
13. C. S. Smith	Principal assistant in the Ordnance Bureau.	Washington, D. C.
14. S. E. Blunt (lieut. col.)	Aide-de-camp to the Lieutenant-General, and inspector of rifle practice at the Headquarters of the Army.	Washington, D. C.

STATIONS AND DUTIES OF OFFICERS, &c.—Continued.

Rank and name.	Duty.	Address.
CAPTAINS—continued.		
15. F. Heath	Assistant, Watervliet Arsenal	West Troy, N. Y.
16. D. M. Taylor	On special duty in the office of the Adjutant-General.	Washington, D. C.
17. D. A. Lyle	On foundry duty, and member of the Board on Life-saving Apparatus, &c., under the Secretary of the Treasury, and member of Board for Testing Rifled Cannon, &c.	Boston, Mass. P. O. box 2253.
18. J. Rockwell, jr	Assistant, Rock Island Arsenal	Rock Island, Ill.
19. J. C. Ayres	Assistant, Benicia Arsenal	Benicia, Cal.
20. M. W. Lyon	Assistant, Watertown Arsenal	Watertown, Mass.
21. C. W. Whipple	Assistant to the Ordnance Board	Governor's Island, New York City. Post-office box 1449.
22. A. H. Russell	Commanding the Vancouver Barracks Ordnance Depot, and chief ordnance officer, Department of the Columbia.	Vancouver, Wash.
23. R. Birnie, jr	On duty in the Office of the Chief of Ordnance.	Washington, D. C.
24. I. MacNutt	Assistant, Frankford Arsenal	Philadelphia, Pa.
25. C. C. Morrison	Assistant, Watertown Arsenal	Watertown, Mass.
26. F. Baker	Assistant, Frankford Arsenal	Philadelphia, Pa.
FIRST LIEUTENANTS.		
1. O. B. Mitcham	Assistant instructor of ordnance and gunnery, U. S. Military Academy.	West Point, N. Y.
2. H. D. Borup	On foundry duty	Boston, Mass. Post-office box 2253.
3. L. L. Bruff	On foundry duty	Cold Spring, N. Y.
4. C. H. Clark	Assistant, National Armory	Springfield, Mass.
5. W. M. Medcalfe	Assistant to the Ordnance Board	Governor's Island, New York City. Post-office box 1449.
6. William Crozier	Assistant, Watertown Arsenal	Watertown, Mass.
7. W. B. Gordon	Instructor of philosophy, U. S. Military Academy.	West Point, N. Y.
8. F. E. Hobbs	On foundry duty	Station G, Philadelphia, Pa.
9. D. A. Howard	On foundry duty	Cold Spring, N. Y.
10. S. E. Stuart	Instructor of philosophy, U. S. Military Academy.	West Point, N. Y.
ORDNANCE STOREKEEPERS.		
Captains.		
A. S. M. Morgan	On duty, Allegheny Arsenal	Pittsburgh, Pa.
W. H. Rexford	On duty, Indianapolis Arsenal	Indianapolis, Ind.
D. J. Young	On duty, Watervliet Arsenal	West Troy, N. Y.
M. J. Grealish	On duty, Augusta Arsenal	Augusta, Ga.
V. McNally	On duty in the Office of the Chief of Ordnance.	Washington, D. C.

8	ounces iodine.
397	pounds iron and its preparations.
14	gallons molasses.
554⅓	pounds mercury and its salts.
150	pounds manganese and its salts.
8	ounces nitrate of silver.
17	gallons spirits of nitre.
30	pounds strontia nitrate.
10	pounds sulphur.
15,180½	pounds sal soda.
3,852	pounds silicate of soda.
44,350	pounds straw boards.
178½	pounds sal ammoniac.
5,430½	pounds potash, various.
217⅗	reams paper.
114,430	pounds paper.
25	pounds tobacco.
3,058	pounds tallow.
20	gallons whisky.

PAINTS, OILS, ETC.

300	pounds asphaltum.
311	gallons benzine.
600	gallons coal tar.
230¼	gallons drier.
33,987	gallons gasoline.
3,079	pounds gilders' whiting.
745	pounds kalsomine.
50	gallons lacker.
515	pounds lampblack.
576	pounds litharge.
180	pounds black lead.
1,080	pounds red lead.
51,162	pounds white lead.
60	pounds extract of logwood.
521¼	gallons naphtha.
57	pounds nut-galls.
32¼	gallons castor oil.
220	gallons cod-liver oil.
636½	gallons dressing oil.
1,988	gallons illuminating oil.
11,140¾	gallons lubricating oil.
6,188¾	gallons oil, mixing paint.
15,541	pounds paint, dry.
11,515	pounds paint, in oil.
127½	gallons paint, in oil.
847	pounds putty.
2,651	gallons petroleum, &c.
200	pounds petroleum, &c.
6	gallons shellac.
1,510	pounds shellac.
1,342½	gallons spirits of turpentine.
1,126	pounds burnt umber.
70	pounds raw umber.
789½	gallons varnish.

2,831	pounds whiting.
715	pounds zinc.

MISCELLANEOUS.

280	barrels.
16	baskets.
15,300	pasteboard boxes.
637	packing boxes.
33,701	tin boxes.
20	gallons browning mixture.
248	tin cans.
12	boxes axle grease.
1,149	pounds axle grease.
6	horses.
5	sets harness.
90	parts harness.
3,084$\frac{1}{2}$	feet hose.
2	hose reels.
11,567	pounds Japan wax.
870$\frac{3}{4}$	pounds packing, various.
500	powder canisters, 2 pounds.
500	powder canisters, 5 pounds.
2	rubber aprons.
4	rubber caps.
6	rubber coats.
17	pairs rubber boots.
42	pairs rubber shoes.
88,152	rubber rings.
57	pounds rubber rings, &c.
61	pounds sheet rubber.
112	feet rubber tubing.
1,000	trees.
652	tickets, railroad and street car.
21	loads saw dust.
20$\frac{1}{2}$	barrels saw dust.
9	whips.
1	wagon.
50	parts of wagons.
6$\frac{1160}{2240}$	tons fertilizers.
2	boats.
20	fly nets.
25,340	wood hoops.
24	tin cups.
24	finger cots.
12	horse covers.
2$\frac{100}{2240}$	tons fluer spar.

MACHINES.

1	band saw, with table complete.
1	bolt-heading machine.
1	creasing machine.
4	drilling machines.
4	force pumps.
1	fire plug.

16 pounds lamp-wick.
134 lamp wicks.
343 pounds lubricating compound.
46½ gross matches.
33 mops and handles.
139 pounds paraffine.
150 pounds pumice stone.
275 pounds rosin.
409 pounds rotten stone.
50 pounds rubber cement.
62 reams sand paper.
5,796 pounds sea-coal facings.
110 barrels sea-coal facings.
4,821 pounds soap.
759 gallons soft soap.
288 pounds sponge.
18 stoves.
57 parts of stoves.
25 pounds stove-polish.
48 papers stove-polish.
940½ feet stove-pipe.
198½ pounds stove-pipe.
798 feet steam-pipe covering.
2,061 papers tripoli.
12½ pounds polishing wheels.
25 pounds quartz.

MATERIALS FOR OFFICE USE.

9 baskets.
50 sheets oil boards.
1,400 sheets card boards.
6 caligraphs, type-writers, &c.
13 chairs, stools, &c.
1 clock.
3,500 dials for watch clock.
46 drawing instruments.
16 pans drawing paint.
12 bottles drawing paint.
6 electrotypes.
26,575 envelopes.
6 ink erasers.
4 hektographs.
91 bottles ink.
1,906 pounds printers' ink.
10 pieces India ink.
30 bottles India ink.
18 pieces India-rubber.
25,700 labels.
60 boxes labels.
20,000 paper seals.
1 letter-press.
22 reams letter paper.
22 boxes paper fastenners.
146½ gross pens.
120 pencils.

144 pencil-point protectors.
6 spools ribbons.
$29\frac{1}{20}$ gross rubber bands.
58 rubber stamps.
202 pounds sealing-wax.
9,200 tags.
25 yards tape.
240 thumb-tacks.
160 yards tracing cloth.
2 boxes eyelets.
49 sheets stencil boards.

LABORATORY STORES.

61 bottles and vials.
10 barometers and thermometers.
9,984 corks.
298 crucibles.
42 gauge glasses.
2 glass breakers.
52 glass tubes.
1 graduate.
2 hydrometers.
35 jars.
13 level glasses.
3 electric batteries.
200 pounds zinc batteries.
1,316 materials for electric batteries.
2 retorts.
$36,280\frac{3}{4}$ pounds acid.
$46\frac{1}{4}$ gallons acid.
$1,634\frac{5}{8}$ gallons alcohol.
60 pounds alum.
70 pounds ammoniated copper.
258 pounds antimony.
6 gallons aqua ammonia.
$567\frac{3}{4}$ pounds beeswax.
150,341 pounds bone.
683 pounds borax.
138 pounds camphor.
211 pounds chalk.
50 pounds powdered charcoal.
1,016 pounds chloride of lime.
108 boxes concentrated lye.
240 pounds electropoin fluid.
$4,123\frac{1}{2}$ pounds glue.
50 pounds glycerine.
10 pounds gelatine.
12 bottles gold chloride.
200 pounds ground glass.
65 pounds gum arabic.
46 pounds gum tragacanth.
25 pounds ground pepper.
132 hand grenades.
394 gallons isinglass.
10 pounds isinglass.

8	ounces iodine.
397	pounds iron and its preparations.
14	gallons molasses.
554½	pounds mercury and its salts.
150	pounds manganese and its salts.
8	ounces nitrate of silver.
17	gallons spirits of nitre.
30	pounds strontia nitrate.
10	pounds sulphur.
15, 180½	pounds sal soda.
3, 852	pounds silicate of soda.
44, 350	pounds straw boards.
178½	pounds sal ammoniac.
5, 430½	pounds potash, various.
217⅗	reams paper.
114, 430	pounds paper.
25	pounds tobacco.
3, 058	pounds tallow.
20	gallons whisky.

PAINTS, OILS, ETC.

300	pounds asphaltum.
311	gallons benzine.
600	gallons coal tar.
230¼	gallons drier.
33, 987	gallons gasoline.
3, 079	pounds gilders' whiting.
745	pounds kalsomine.
50	gallons lacker.
515	pounds lampblack.
576	pounds litharge.
180	pounds black lead.
1, 080	pounds red lead.
51, 162	pounds white lead.
60	pounds extract of logwood.
521¼	gallons naphtha.
57	pounds nut-galls.
32¼	gallons castor oil.
220	gallons cod-liver oil.
636½	gallons dressing oil.
1, 988	gallons illuminating oil.
11, 140¾	gallons lubricating oil.
6, 188¾	gallons oil, mixing paint.
15, 541	pounds paint, dry.
11, 515	pounds paint, in oil.
127½	gallons paint, in oil.
847	pounds putty.
2, 651	gallons petroleum, &c.
200	pounds petroleum, &c.
6	gallons shellac.
1, 510	pounds shellac.
1, 342½	gallons spirits of turpentine.
1, 126	pounds burnt umber.
70	pounds raw umber.
789½	gallons varnish.

2,831	pounds whiting.
715	pounds zinc.

MISCELLANEOUS.

280	barrels.
16	baskets.
15,300	pasteboard boxes.
637	packing boxes.
33,701	tin boxes.
20	gallons browning mixture.
248	tin cans.
12	boxes axle grease.
1,149	pounds axle grease.
6	horses.
5	sets harness.
90	parts harness.
3,084½	feet hose.
2	hose reels.
11,567	pounds Japan wax.
870¾	pounds packing, various.
500	powder canisters, 2 pounds.
500	powder canisters, 5 pounds.
2	rubber aprons.
4	rubber caps.
6	rubber coats.
17	pairs rubber boots.
42	pairs rubber shoes.
88,152	rubber rings.
57	pounds rubber rings, &c.
61	pounds sheet rubber.
112	feet rubber tubing.
1,000	trees.
652	tickets, railroad and street car.
21	loads saw dust.
20½	barrels saw dust.
9	whips.
1	wagon.
50	parts of wagons.
$6\frac{1160}{2240}$	tons fertilizers.
2	boats.
20	fly nets.
25,340	wood hoops.
24	tin cups.
24	finger cots.
12	horse covers.
$2\frac{100}{2240}$	tons fluer spar.

MACHINES.

1	band saw, with table complete.
1	bolt-heading machine.
1	creasing machine.
4	drilling machines.
4	force pumps.
1	fire plug.

8	ounces iodine.
397	pounds iron and its preparations.
14	gallons molasses.
554⅛	pounds mercury and its salts.
150	pounds manganese and its salts.
8	ounces nitrate of silver.
17	gallons spirits of nitre.
30	pounds strontia nitrate.
10	pounds sulphur.
15,180½	pounds sal soda.
3,852	pounds silicate of soda.
44,350	pounds straw boards.
178½	pounds sal ammoniac.
5,430½	pounds potash, various.
217⅗	reams paper.
114,430	pounds paper.
25	pounds tobacco.
3,058	pounds tallow.
20	gallons whisky.

PAINTS, OILS, ETC.

300	pounds asphaltum.
311	gallons benzine.
600	gallons coal tar.
230¼	gallons drier.
33,987	gallons gasoline.
3,079	pounds gilders' whiting.
745	pounds kalsomine.
50	gallons lacker.
515	pounds lampblack.
576	pounds litharge.
180	pounds black lead.
1,080	pounds red lead.
51,162	pounds white lead.
60	pounds extract of logwood.
521¼	gallons naphtha.
57	pounds nut-galls.
32¼	gallons castor oil.
220	gallons cod-liver oil.
636½	gallons dressing oil.
1,988	gallons illuminating oil.
11,140¾	gallons lubricating oil.
6,188¾	gallons oil, mixing paint.
15,541	pounds paint, dry.
11,515	pounds paint, in oil.
127½	gallons paint, in oil.
847	pounds putty.
2,651	gallons petroleum, &c.
200	pounds petroleum, &c.
6	gallons shellac.
1,510	pounds shellac.
1,342½	gallons spirits of turpentine.
1,126	pounds burnt umber.
70	pounds raw umber.
789½	gallons varnish.

2,831 pounds whiting.
715 pounds zinc.

MISCELLANEOUS.

280 barrels.
16 baskets.
15,300 pasteboard boxes.
637 packing boxes.
33,701 tin boxes.
20 gallons browning mixture.
248 tin cans.
12 boxes axle grease.
1,149 pounds axle grease.
6 horses.
5 sets harness.
90 parts harness.
3,084½ feet hose.
2 hose reels.
11,567 pounds Japan wax.
870¾ pounds packing, various.
500 powder canisters, 2 pounds.
500 powder canisters, 5 pounds.
2 rubber aprons.
4 rubber caps.
6 rubber coats.
17 pairs rubber boots.
42 pairs rubber shoes.
88,152 rubber rings.
57 pounds rubber rings, &c.
61 pounds sheet rubber.
112 feet rubber tubing.
1,000 trees.
652 tickets, railroad and street car.
21 loads saw dust.
20½ barrels saw dust.
9 whips.
1 wagon.
50 parts of wagons.
$6\frac{1168}{2240}$ tons fertilizers.
2 boats.
20 fly nets.
25,340 wood hoops.
24 tin cups.
24 finger cots.
12 horse covers.
$2\frac{100}{2240}$ tons fluer spar.

MACHINES.

1 band saw, with table complete.
1 bolt-heading machine.
1 creasing machine.
4 drilling machines.
4 force pumps.
1 fire plug.

1	grappling hay fork.
3	grinding machines.
3	lawn mowers.
375	parts of mowing machine.
15	lathes.
138	parts of machines, various.
1	metal-working machine (No. 4 double seaming machin complete).
2	mowing machines.
1	planing machine.
1	pipe-cutting and threading machine.
1	portable furnace.
1	slotting machine.
2	saw arbors, complete.
1	shaping machine.
1	scraper (2-horse, wheel).
5	steam boilers.
1	steam heating apparatus.
3	screw machines.
15	parts screw machine.
1	water elevator.
6	wood-working machines, viz:
1	band-saw filing machine.
1	band-saw setting machine.
2	yoke saw arbors.
1	"buck" groover head.
1	16-inch wood-turning lathe head.
2	Boulengé chronographs.
1	engineer's transit.
1	Vernier caliper.

TOOLS.

152	awls.
41	axes.
72	bits.
3	braces.
3,184	brushes and sash tools.
183	buckets.
684	carpenters' tools, various.
999$\frac{3}{4}$	pounds chalk lines.
132	chisels.
7	chucks.
56	coal hods.
8	clamps.
725	drills.
13	sets drills.
125	drifts.
4	grass hooks.
43	die and stocks.
15,764	files.
127	forks (hay and manure.)
3	gauges.
1	set gauges.
116,265	pounds grindstones.
260	hatchets and hammers.
1	harrow.

1,294	handles.
66	hoes.
239	knives, saddlers', &c.
2	kettles.
2	ladders.
4	sets letters and figures.
327	mallets.
4	measures.
25	pairs nippers.
344	papers needles.
323	oil cups and oilers.
311	oil stones.
16	planes.
16	plane irons.
4	plows.
4	plow points.
19	picks.
361	punches, assorted.
169	rakes.
2,522	rasps.
12	rivet sets.
92	rules.
1.919	smiths' tools, various.
41	saddlers' tools, various.
46	sandstones.
42	spades.
221	shovels.
2	platform scales.
2	counter scales.
73	saws.
369	saw blades.
45	pair shears.
412	screw drivers.
134	scythes.
197	scythe stones.
69	scythe snaths.
46	sieves and sifters.
13	steel stamps.
49	stencil letters.
2	trucks.
3	tinners' tools, various.
1	tire setter.
12	tape lines.
109	taps and reamers.
3	sets taps and reamers.
3	trowels.
125	vises.
214	wrenches.
50	wheelbarrows.

APPENDIX 3.

Statement of ordnance, ordnance stores, &c., issued to the military establishment, including the national homes for soldiers of the volunteer and regular Army, and exclusive of the militia, during the fiscal year ended June 30, 1886.

CLASS I.

1 Gatling gun, 5 short barrels, caliber .45".
3 Gatling guns, 10 long barrels, caliber .45"
2 Hotchkiss mountain guns, caliber 1."65.
1 6-pounder bronze gun.
1 10-pounder Parrott gun.
5 light 12-pounder bronze guns.
1 12-pounder mountain howitzer.
3 8-inch converted rifles.
2 11-inch converted rifles.

CLASS II.

2 Gatling gun carts.
2 Gatling gun carriages and limbers.
2 Hotchkiss mountain gun carriages.
3 6-pounder gun carriages.
4 3-inch gun carriages.
8 4.5-inch gun carriages.
10 12-pounder gun carriages.
4 8-inch howitzer carriages.
6 8-inch barbette carriages.
1 11-inch barbette carriage.
12 3-inch gun caissons.
4 12-pounder gun caissons.
8 portable forges with tools, complete.

CLASS III.

136 harness bags.
2 maneuvering bars.
5 pinch bars.
3 baskets for mortar implements.
2 wooden forge buckets.
5 iron sponge buckets.
10 wooden sponge buckets.
4 iron tar buckets.
119 gutta-percha water buckets.
8 leather water buckets.

4 wooden water buckets.
2 elevating arcs, 11-inch rifle.
2 elevating arcs and indices, 8-inch rifle.
1 elevating arc and index, 11-inch rifle.
1 elevating arc and index, 15-inch gun.
2 elevating arcs and trunnions, 11-inch rifle.
4 indices, 15-inch gun.
14 fuse-blocks.
5 fuse cutters.
1 fuse plug reamer.
37 gunners' gimlets.
9 gunners' haversacks.
3 gunners' levels.
6 gunners' pincers.
5 gunners' quadrants.
14 breech sights, 8-inch gun.
8 breech sights, 15-inch gun.
3 breech-sight seats and screws.
2 muzzle sights, 3-inch gun.
4 muzzle sights, 12-pounder gun.
12 muzzle sights, 8-inch gun.
1 muzzle sight, 15-inch gun.
24 handspikes, maneuvering.
12 handspikes, 8-inch rifle.
17 handspikes, trail.
1 handspike, mountain howitzer.
2 sets harness, 1-horse, Hotchkiss mountain gun.
12 sets harness, 2-lead horses.
19 sets harness, 2-wheel horses.
2 sets harness, Laidley cavalry forge.
2 sets harness, mountain howitzer carriage.
1 common lantern.
1 dark lantern.
13 globe lanterns.
8 magazine lanterns.
51 lanyards.
2 muzzle covers.
2 pack saddles and bridles.
2 packing pouches.
13 paulins, 8 by 10 feet.
96 paulins, 12 by 15 feet.
10 pendulum hausses, 3-inch gun.
7 pendulum hausses, 12-pounder gun.
19 pendulum hausse pouches.
3 powder funnels.
4 powder measures.
2 powder scoops.
18 priming wires, field gun.
68 priming wires, siege gun.
25 prolonges.
4 quoins.
1 rammer and staff, 3.2-inch gun.
2 rammers and staves, 4.5-inch gun.
10 rammers and staves, 8-inch rifle.
4 rammers and staves, 11-inch rifle.
100 securing stakes.

9 shell hooks.
39 sponge covers, 3-inch gun.
2 sponge covers, 3.2-inch gun.
4 sponge covers, 6-pounder.
52 sponge covers, 12-pounder.
12 sponge covers, mountain howitzer.
28 sponges and rammers, 3-inch gun.
1 sponge and rammer, 3.2-inch gun.
12 sponges and rammers, 6-pounder gun.
27 sponges and rammers, 12-pounder gun.
11 sponges and rammers, mountain howitzer.
4 sponges and staves, Hotchkiss mountain gun.
2 sponges and staves, 4.5-inch gun.
18 sponges and staves, 8-inch rifle.
64 thumbstalls.
6 tompions, 6-pounder gun.
16 tompions, 3-inch gun.
10 tompions, 12-pounder gun.
1 tompion, mountain howitzer.
4 tompions, 30-pounder gun.
7 tompions, 4.5-inch gun.
54 tompions, 8-inch gun.
2 tompions, 10-inch gun.
4 tompions, 11-inch rifle.
12 tompions, 13-inch gun.
40 tompions, 15-inch gun.
1 tompion, 20-inch gun.
33 tube pouches.
85 vent covers.
53 vent pieces.
32 vent punches.
5 water tubs.
56 wipers for mortars.
18 worms and staves.

IMPLEMENTS FOR GATLING GUN.

1 cam extractor.
3 clamps for worm gear.
3 drifts.
2 elevating screws.
194 feed cases.
4 feed magazines.
2 gun beds and frames.
6 gun covers.
4 handspikes.
4 headless shell extractors.
2 pointing levers.
1 oscillator.
4 lock screw drivers.
4 small screw drivers.
4 T screw drivers.
3 shell drivers.
4 wiping rods.
5 adjusting screw wrenches.
1 elevating screw wrench.

4	pin wrenches.
3	rear-guide nut wrenches.
2	sets accessories, Hotchkiss mountain gun.
3	covers Hotchkiss mountain gun.

Classes IV and V.

50	6-pounder shot.
250	3-inch shot.
80	4.5-inch shot.
100	30-pounder shot.
950	8-inch shot.
100	10 inch shot.
35	11-inch shot.
200	15-inch shot.
100	1.5-inch shell and cartridge case.
20	2.9-inch shell.
3,834	3-inch shell.
520	3.2-inch shell.
166	4.5-inch shell.
50	30-pounder shell.
100	8-inch mortar shell.
260	10-inch gun shell.
100	10-inch mortar shell.
100	13-inch mortar shell.
1	20-inch gun shell
80	6-pounder case shot.
417	3-inch case shot.
130	3.2-inch case shot.
100	12-pounder case shot.
20	6-pounder canister
886	3-inch canister.
100	12-pounder canister.

Class VI.

2,140	Springfield carbines, caliber .45″.
735	Colt's revolvers, caliber .45″
24	Schofield's Smith and Wesson revolvers, caliber .45″.
1	Chaffee-Reece magazine rifle, caliber .45″.
1	Lee magazine rifle, caliber .45″.
17,796	Springfied rifles, caliber .45″.
50	Springfield cadet rifles, caliber .45″.
15	Springfield shotguns.
5	artillery sabers.
151	cavalry sabers.
53	musicians' swords.
46	non-commissioned officers' swords.
163	hunting knives.

Class VII.

ARTILLERY ACCOUTERMENTS.

50	knapsacks for light battery.
169	saber belts.
165	saber-belt plates.

CAVALRY ACCOUTERMENTS.

541	canteens and straps with snaps.
1,286	canteen straps.
1	cartridge belt, woven.
1,334	carbine slings.
997	carbine-sling swivels.
1,596	pistol holsters.
1,094	saber attachments.
2,110	saber belts.
2,104	saber-belt plates.
1,225	saber knots.
423	pairs saber straps.

INFANTRY ACCOUTERMENTS.

2,225	bayonet scabbards, steel.
20	bayonet scabbards, trowel bayonet.
1,370	blanket bags.
150	blanket and coat straps.
2,582	blanket bag coat straps.
2,732	blanket bag shoulder straps.
6,116	canteens.
124	canteen covers.
15	canteen corks and chains.
3,181	canteen straps.
2,875	cartridge belts.
1,441	cartridge-belt plates.
4,090	cartridge boxes.
50	cartridge boxs, shotgun cartridges.
2,811	clothing bags.
2,782	clothing-bag straps.
4,521	forks.
4,721	knives.
4,532	spoons.
205	frogs, bayonet scabbard.
24	frogs, sliding.
5,620	gun slings.
2,118	haversacks.
1,988	haversacks and straps.
2,525	haversack straps.
30	intrenching tool scabbards.
4,318	meat cans.
5,759	tin cups.
30	waist belts and plates, non-commissioned officers'.
4,712	waist belts.
4,388	waist-belt plates.

APPENDAGES.

95	brushes and thongs.
48	bullet molds.
17,400	headless shell extractors.
17,074	screw drivers.
423	screw drivers, revolver.
1	screw driver, Lee rifle.

814	spring vises.
3,257	tumbler punches.
2	wiping brushes, Lee rifle.
17	wiping rods, shotgun.
23,230	wiping rods, wood.
20	wire caliber brushes.
27	wire scratch brushes.

HORSE EQUIPMENTS.

2,971	curb bridles.
1,008	watering bridles.
10	carbine sockets and straps.
5,260	carbine boots and straps.
892	cinchas or hair girths.
3,489	curry combs.
187	cruppers.
80	forage sacks.
12	girths.
3,464	halters.
6,052	halter straps.
5,192	horse brushes.
2,103	horse covers.
3,064	lariats.
2,509	links.
4,998	nose bags.
1,775	picket pins.
9,257	saber straps for cavalry saddle.
1,154	saddles.
32	saddle bags, canvas.
869	saddle bags, leather.
4,303	saddle blankets.
50	saddle cloths, hair.
1,664	side lines.
72	side-line fasteners.
89	spurs and straps, Mills'.
2,609	spurs.
2,010	spur straps.
3,925	stirrups.
3	stirrups with guidon sockets.
1,340	stirrup straps.
2,290	surcingles.

CLASS VIII.

SMALL-ARM AMMUNITION.

1,469,000	carbine ball cartridges, caliber .45″.
289,469	revolver ball cartridges, caliber .45″.
296,000	revolver blank cartridges, caliber .45″.
3,750,100	rifle ball cartridges, caliber .45″.
10,000	rifle ball cartridges, caliber .50″.
385,000	rifle blank cartridges, caliber .45″.
1.110,925	round balls, caliber .45″.
2,263,000	carbine bullets, caliber .45″.
348,000	revolver bullets, caliber .45″.

6,998,300	rifle bullets, caliber .45″.
155,567	pounds small-arm powder.
12,613,800	cartridge primers.
12,264	cartridge shells.
25	pounds buckshot.
18,025	pounds shot.
4,168,500	cartridge wads.
35	shotgun outfits, except tools and cases.

AMMUNITION FOR CANNON.

8,028	blank cartridges, ½-pound charge.
2,280	blank cartridges, 1-pound charge.
1,676	blank cartridges, 1½-pound charge.
18,754	blank cartridges, 2-pound charge.
7,670	blank cartridges, 6-pounder gun.
18,814	blank cartridges, 3-inch gun.
120	blank cartridges, 3.2 inch gun.
5,950	blank cartridges, light 12-pounder gun.
8,300	blank cartridges, mountain howitzer.
145	metallic fuzes.
1,800	paper fuzes.
150	percussion fuzes.
11,600	pounds cannon powder.
25,500	pounds hexagonal powder.
5,000	pounds mammoth powder.
350	pounds mealed powder.
20,200	pounds mortar powder.
2,010	electric primers.
159,228	friction primers.

CLASS IX.

189	arm racks.
1,824	sharpshooters' badges.
337	silver bars for sharpshooters' badges.
282	assorted blocks.
15,308	marksman's buttons.
1	capstan.
4	capstan bars.
1	hand cart.
7	sling chains.
86	assorted chocks.
1	gun collar.
6	cranes.
150	disks, shot mark.
12	fencing bayonet blades.
12	fencing masks.
12	fencing muskets.
433	signal flags.
1	casemate gin.
1	field and siege gin.
2	garrison gins.
2	gin falls.
2	gin handspikes.
282	halyards.
30	intrenching tools.

3	hydraulic jacks.
2,242	marksman's pins.
8	marking rods, disks, and brushes.
4	mortar platforms.
500	muzzle plugs.
13	pinch bars.
33	shifting planks.
13	plates for gallery practice.
6	differential pulleys.
52	assorted rollers.
1	sheave, gun lift.
498	shot marks and staves.
24	skids.
317	streamers.
2	plane tables.

PARTS OF BRINTON TARGET.

36	targets, complete.
4	carriages.
90	clamps.
261	frames.
2	hooks.
6	pulleys.
4	pairs rods.

PARTS CUSHING'S TARGET.

43	targets, complete.
30	braces.
15	cross pieces.
112	frames.
51	truck frames.
12	truck wheels.

PARTS OF LAIDLEY'S TARGET.

357	targets, complete.
48	axles.
3	axles, with pins and wedges.
10	center-blocks and pins.
62	journal boxes.
51	lever boxes.
148	nave boxes.
8	braces.
259	cross pieces.
6,435	steel frames.
10	journal posts.
91	levers.
35	springs, with blocks.
569	uprights.
70,924	paper targets.
21	Texas targets.
19,645	target centers.
354	target covers.
1,513	target frames.

14,507,250	target pasters.
515	target rails.
17,068	cloth silhouettes.
115,577	paper silhouettes.
2	trace ropes.
3	pairs eccentric trunnion rings.
72	trunnion rings.

RELOADING-TOOLS, ETC.

49	sets bench tools, complete.
47	sets hand tools, complete.
88	combination anvils.
7	ball molds.
132	brush wipers.
21	adjustable powder chargers.
1	bench crimping die.
37	crimping and reloading dies for revolver cartridges.
118	crimping and reloading dies for rifle cartridges.
109	bench resizing dies.
39	resizing dies for revolver shells.
357	resizing dies for rifle shells.
42	drifts.
2	primer extractors.
94	primer extractor pins.
21	funnels.
35	ladles.
255	mallets.
29	oil cans.
91	priming tools.
617	priming tool pins.
15	reloading punches for revolver cartridges.
171	reloading punches for rifle cartridges.
244	resizing punches.
36	shell scrapers.
7	strainers.
1	uncapping bolt for priming tool.
3	washers.
20	wiping rods.

TOOLS FOR SHOTGUN OUTFITS.

28	brush wipers.
26	canisters.
4	drifts.
2	field cases.
4	funnels.
2	priming tools.
20	powder and shot chargers.

CLASS X.

PARTS OF CLASS I.

6	firing pins for Gatling gun.
4	pointing rings for 3-inch rifle.
1	steel breech bushing for 12-inch rifle.
1	steel tube for 12-inch rifle.

PARTS OF CLASS II.

4 eccentric axles.
1 assembling bar.
1 assembling stud bolt.
30 bolts and nuts.
1 foot board for cavalry forge.
1 front prop catch, rod, and ring for cavalry forge.
10 hounds.
6 keys for ammunition chest.
5 linch pins.
2 naves for cavalry forge.
2 oilers for Gatling gun carriage.
40 poles.
4 pole lifts.
10 pole yokes.
2 rails.
1 rear prop pull, rod, and ring for cavalry forge.
6 retracting ropes, hemp.
2 retracting ropes, steel wire.
1 pair shafts.
1 sill for cavalry forge.
1 splinter bar.
6 stay pins for ammunition chest.
1 stock for caisson.
1 stock for carriage.
6 washers.
1 wheel for cavalry forge.
18 wheels.
2 whiffletrees.

PARTS OF CLASS III.

5 brass-plated bits.
32 artillery bridles.
2,197 brass-plated buckles.
427 iron roller buckles.
29 collars.
1 girth.
75 halters.
20 halter chains.
65 halter straps.
1 pair hames.
10 hame-straps.
5 leg guards.
48 pole pads.
21 pole straps.
62 rammer heads.
12 rammer-head bands.
94 rosettes for artillery bridles.
12 leather seats for drivers' saddles.
43 sponge heads.
480 woolen sponges.
14 brass stirrups.
12 lead traces.
4 traces for patent bar.
12 wheel traces.
160 whips.

PARTS OF CLASSES IV AND V.

6	brass tips for shrapnel.
300	copper bands for shell.
40	fuze plugs, metallic.
1,500	fuze plugs, wood.
90	sabots.
40	tin straps.

PARTS OF CLASS VI.

Parts of Springfield carbine.

12	barrel studs.
23	bands.
10	butt plates.
10	butt-plate screws.
272	front sights.
1,038	front-sight covers.
317	front-sight cover screws.
11	front-sight cover springs.
11	front-sight cover friction springs.
4	front-sight cover stud pins.
272	front-sight pins.
1,647	jointed ramrods.
166	rear sights.
35	rear-sight bases.
50	rear-sight base screws.
113	rear-sight leaves.
11	rear-sight joint pins.
952	stocks, wood part.
9	swivel bars.
111	swivel-bar rings.

Parts of Springfield rifle.

11	lower bands.
111	upper bands.
24	band springs.
7	bayonets.
156	bayonet clasps.
502	bayonet-clasp screws.
10	bayonet-clasp stop screws.
6	rod bayonet springs.
66	breech-block caps.
1,756	breech-block cap screws.
2,223	bridles.
2,270	bridle screws.
3	butt plates.
15	butt-plate screws.
2,883	cam-latch springs.
5,845	ejector springs.
5,578	ejector-spring spindles.
131	ejector studs.
3,885	extractors.
6,833	firing pins.

2,859	firing-pin screws.
6	firing-pin springs.
336	front sights.
6,203	front-sight covers.
313	front-sight pins.
3	guard bows.
10	guard-bow nuts.
89	guard-bow swivels.
213	guard-bow swivel screws.
654	guard screws.
147	hammers.
850	hinge pins.
70	hinge-pin studs.
6	locks.
51	lock plates.
1,849	mainsprings.
895	mainspring swivels.
1,210	mainspring swivel rivets.
3,266	pistol grips, metallic.
40	pistol grips, wood.
508	pistol-grip screws.
141	ramrods.
264	ramrod stops.
157	rear sights.
122	rear-sight base screws.
56	rear-sight base springs.
170	rear-sight leaves.
30	rear-sight plates, buckhorn.
68	rear-sight centering pins.
522	rear-sight joint pins.
32	rear-sight slides.
24	rear-sight slide blocks.
130	rear-sight slide gibs.
66	rear-sight slide plates.
58	rear-sight slide screws.
94	rear-sight slide springs.
102	rear sight screws.
56	leaf-slide binding screws.
56	windage screws.
1,706	sears.
3,858	sear screws.
2,455	sear springs.
1,320	sear-spring screws.
494	side screws.
122	side-screw washers.
549	stocks, wood part.
305	tang screws.
18	thumb pieces.
12	stock tips.
14	tip screws.
15	triggers for officer's rifle.
3,400	triggers.
1,163	trigger screws.
2,231	tumblers.
125	tumblers, swiveled.
2,878	tumbler screws.

5 firing pins for Chaffee-Reece rifle.
5 firing pins for Hotchkiss rifle.
5 firing pins for Lee rifle.
1 magazine for Lee rifle.
2 ejector springs for Springfield shotgun.
86 extractors for Springfield shotgun.
3 stocks for Springfield shotgun.

Parts of Colt's revolver.

20 back straps.
291 back-strap screws.
88 bolts.
132 bolt screws.
121 center pins.
70 center-pin bushings.
349 center-pin catch screws.
30 center-pin screws.
50 cylinders.
95 ejector heads.
139 ejector rods.
120 ejector springs.
24 ejector tubes.
122 ejector-tube screws.
70 firing pins.
70 firing-pin rivets.
10 frames.
20 gates.
10 gate catches.
26 gate-catch screws.
51 gate springs.
10 guards.
212 guard screws.
167 hammers.
20 hammer cams.
7 hammer rolls.
5 hammer roll rivets.
101 hammer screws.
120 hands.
192 hand springs.
135 main springs.
127 main-spring screws.
15 recoil plates.
81 sear springs.
53 sear-spring screws.
144 sear and stop-bolt springs.
81 sear and stop-bolt spring screws.
11 stocks.
143 triggers.
130 trigger-screws.

Parts of Schofield's Smith & Wesson Revolver.

6 barrel catches.
10 barrel-catch screws.
10 barrel-catch springs.

5 base pins.
4 cylinder catches.
4 cylinder catch cams.
6 cylinder catch screws.
12 ejector springs.
6 extractors.
3 extractor springs.
4 extractor stems.
6 extractor studs.
3 friction collars.
3 guard screws.
4 hammers.
4 hammer studs.
10 hands.
10 hand pins.
10 hand springs.
3 joint pivots.
4 joint-pivot screws.
3 lifters.
2 main springs.
2 main-spring swivels.
3 pawls.
3 pawl pins.
3 pawl springs.
4 side-plate screws.
6 stocks.
6 stock pins.
8 stock screws.
3 stops.
3 stop pins.
3 stop springs.
3 strain screws.
4 swivel pins.
2 triggers.
2 trigger pins.
4 trigger springs.
4 trigger-spring pins.
1 steel scabbard for musician's sword.

PARTS OF CLASS VII.

11 curb bits.
100 bridle ornaments.
6,366 brass bar buckles.
3,514 brass wire buckles.
1,470 iron bar buckles.
3,105 iron roller buckles.
259 cincha straps.
190 coat straps.
65 curb straps.
20 girth straps.
1,480 double-spring snap hooks.
2,668 gross brass escutcheon pins.
196 halter bolts.
6 halter chains.
312 halter rings.

498	halter squares.
1,416	japanned nails.
1,960	ovals.
1,940	brass rings.
258	iron D rings.
618	iron rings.
287	canteen strap snaps.
20	link snaps.
120	saber-belt snaps.
300	side-line snaps.
68	steel snaps.
30	saber-belt studs.
12	saddle bag studs.
2,280	brass foot staples.
3,420	brass staples for rings.
200	pairs stirrup hoods.
410	yards webbing, 4 inches wide.
24	yards webbing, 7½ inches wide.

PARTS OF CLASS VIII.

515	cartridge bags, ½-pound charge.
3,200	cartridge bags, 6-pounder gun.
8,750	cartridge bags, 12-pounder gun.
700	cartridge bags, 30-pounder gun.
500	cartridge bags, 32-pounder gun.
380	cartridge bags, 300-pounder gun.
10,991	cartridge bags, 3-inch gun.
500	cartridge bags, 3.2-inch gun.
4,200	cartridge bags, 4.5 inch gun.
1,500	cartridge bags, 8-inch gun.
1,433	cartridge bags, 10-inch gun.
700	cartridge bags, 11-inch gun.
250	cartridge bags, 15-inch gun.
500	fuzes, unfilled.

PARTS OF CLASS IX.

1	leg for sheave for Laidley's gun lift.
1	pry-pole for field gin.

PART SECOND.

CLOTH, ROPE, THREAD, ETC.

200	yards burlaps.
20,095⅛	yards cotton cloth.
267	pounds waste cotton.
30	pounds lanyard cord.
181	pounds sash cord.
10	pounds curled hair.
15	pounds marline.
4,991½	pounds rope.
845	pounds thread.
1,020	pounds tow.
243	pounds twine.

IRONMONGERY.

4	pounds bolts.
66	pairs butts.
1	bushing.
183	pounds chain.
10	brass cocks.
36	pounds copper.
14	pieces copper for vent pieces.
5	hooks.
12	hasps and staples.
17,400	horseshoes.
6	pairs strap hinges.
853	pounds bar iron.
308	pounds band iron.
8	iron ladles.
3	pounds copper nails.
1,743	pounds horseshoe nails.
4,984	pounds iron nails.
357	padlocks.
13	pounds iron plates.
483	pounds steel rails.
240½	pounds brass rivets and burrs.
604	pounds copper rivets and burrs.
61	pounds iron rivets and burrs.
152	gross brass screws.
320	gross iron screws.
1	ounce silver solder.
11¾	pounds solder.
509	pounds spikes.
709	pounds steel.
39,291	copper tacks.
44	papers copper tacks.
70	pounds copper tacks.
1,611,512	iron tacks.
314	papers iron tacks.
119⅝	pounds iron tacks.
150	sheets tin
1	set steel tire.
100	tire bolts.

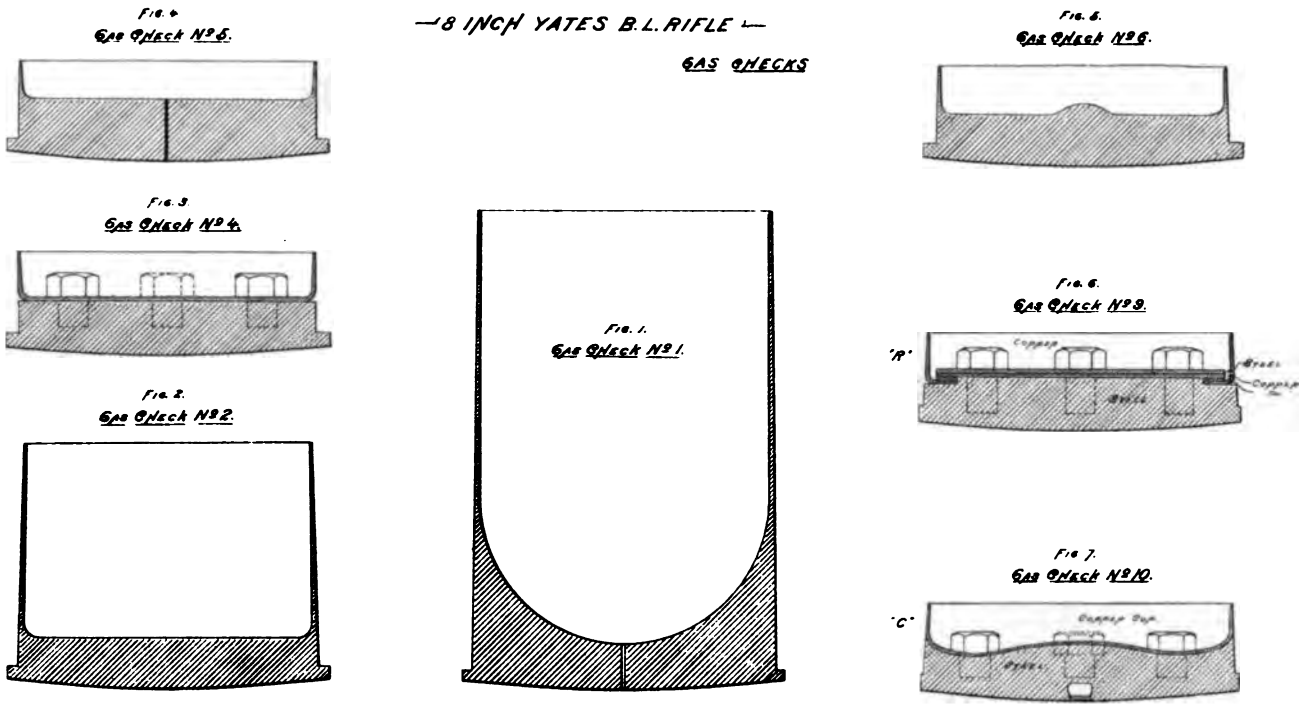
LEATHER, ETC.

892	sides bridle leather.
22,389	pounds harness leather.
5	sides lace leather
2	hides trimming leather.
1	gallon edge blacking.
151	quarts leather blacking.
266½	pounds black wax.
1	pound bristles.
105	boxes ingredients for leather blacking.

LUMBER, ETC.

10,502	feet boards.
3,000	feet plank.

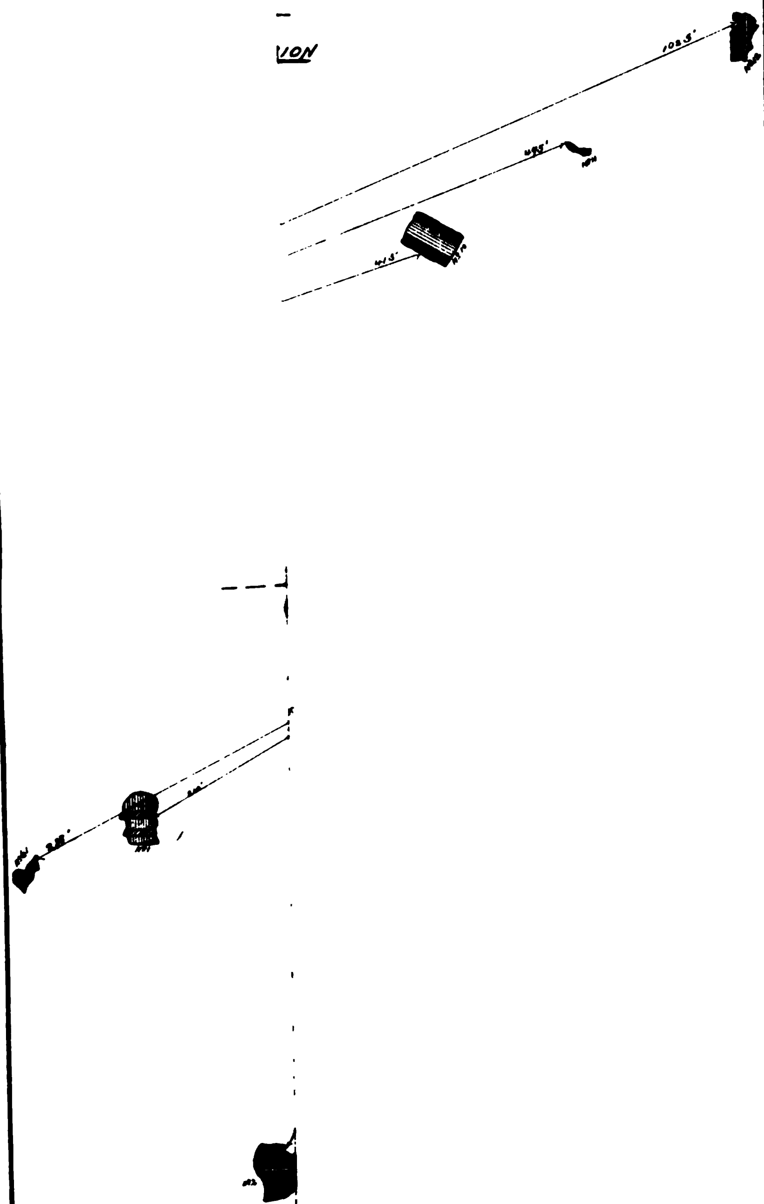
PLATE II.



Appendix 9—1888.

8 Ex1 pt2 v3 40 2

PLATE III.



Appendix 9—1866.

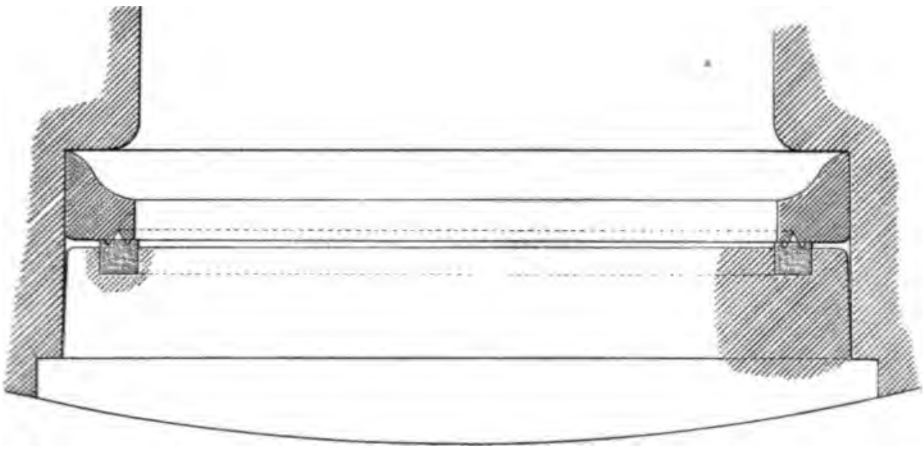


FIG. 2.

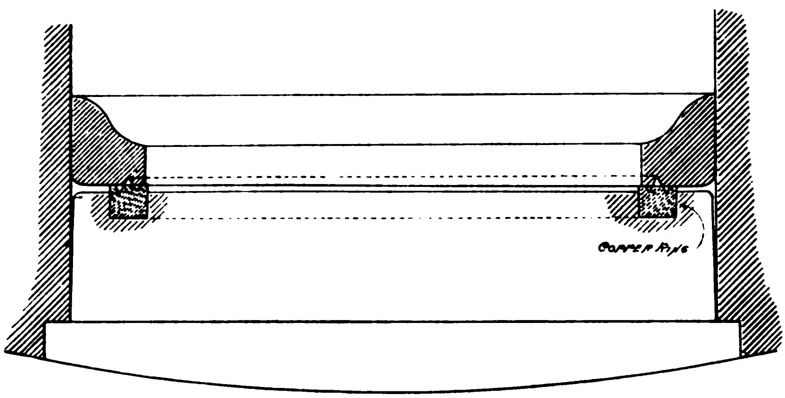


FIG. 1.

4,989 feet scantling.
883 feet timber.
6 barrels cement.

CLEANING, HEATING, AND LIGHTING.

61 bath bricks.
227 corn brooms.
29 dusting brushes.
7 feather dusting brushes.
117 button brushes.
58 button sticks.
14 pounds candles.
88 chamois skins.
14 boxes cleaning material.
7 cleaning plates.
13,001 pounds coal.
47 quires crocus cloth.
10 pounds emery.
2 emery belts.
1,135¾ quires emery cloth.
277½ quires emery paper.
43 pounds lampwicking.
6 lanterns.
144 boxes matches.
3 door mats.
7 pounds polishing material.
136 ounces scouring material.
12 pounds pomade.
524½ pounds rottenstone.
63 quires sand paper.
170 pounds bar soap.
2,261 pounds castile soap.
159 pounds sponge.
627 papers tripoli.

MATERIAL FOR OFFICE USE.

3 waste-paper baskets.
3 half-boxes blacking for stencil outfits.
783 instruction books.
18 fitch brushes.
1 paper cushion buttons.
4 ounces indelible ink.
6 bottles hektograph ink.
20 pounds hektograph composition.
2 hektograph pans.
2 curtain lights.
426 marking outfits.
50 pounds stencil paper.
½ ream wrapping paper.
1,000 pounds wrapping paper.
48 carpenters' pencils.
1,000 paper scales.
4 seal stamps.
115 pounds sealing wax.

2 company stencil plates.
6 sets stencil dies or plates, letters, and figures.
30 sheets stencil board.
10 sets stencil outfits.
100 metal tags.

LABORATORY STORES.

4 pints muriatic acid.
112 gallons alcohol.
50 pounds gum arabic.
134¾ pounds beeswax.
75 pounds camphor.
23 pounds chalk.
70 pounds ammoniated copper.
2 barrels flour.
125 pounds glue.
1,100 pounds paper.
25 pounds black pepper.
40 pounds potash.
20 pounds gum shellac.
30 pounds nitrate of strontia.
10 pounds sulphur.
25 pounds tobacco.
3,811 pounds Japan wax.
20 gallons whisky.

OILS, PAINTS, ETC.

90 gallons coal tar.
2 quarts comolubric.
48⅜ gallons Japan drier.
5 pounds oak graining.
168½ gallons lacker.
23 pounds lampblack.
176 pounds red lead.
1,412 pounds white lead.
11 pounds extract logwood.
1½ gallons anti-corrosive oil.
187½ quarts cosmoline oil.
3,252 pounds harness oil.
220 gallons kerosene oil.
10 gallons lard oil.
762½ gallons linseed oil.
109½ gallons neatsfoot oil.
345 gallons neutral oil.
932½ gallons sperm oil.
10 gallons yellow ochre.
892½ pounds black paint.
2,281 pounds brown paint.
395 pounds green paint.
270 pounds lead-color paint.
1,515 pounds metallic paint.
2,924 pounds olive paint.
5 pounds red paint.
60 pounds vermillion paint.

35 pounds yellow paint.
83 pounds putty.
563½ gallons turpentine.
76 pounds umber.
3 gallons coach varnish.
20 gallons copal varnish.
10 gallons Japan varnish.
16½ pounds whiting.

MISCELLANEOUS.

3 tool bags.
751 wooden powder barrels.
12 steel ammunition boxes.
4 cleaning material boxes.
35 packing boxes.
16 reloading tool boxes.
227 powder canisters.
301 tin cans.
2 field cases.
30 chamois-skin saber cases.
46 chamois-skin sword cases.
1,059 arm chests.
4 forge chests.
3 tool chests.
6 boxes axle grease.
860 pounds wheel grease.
120 barrel hoops.

MACHINES AND PARTS OF MACHINES.

1 calipers.
3 sets measuring points for star gauge.
3 ring gauges for star gauges.
2 pieces shafting with pulleys.
1 star-gauge points.
1 card wheel for revolving scratch brush.

TOOLS.

1 adze.
12 anvils.
210 aprons.
519 assorted awls.
178 awl handles.
35 axes.
9 axe handles.
1 bellows, smiths.
77 assorted bits.
13 lead punching blocks.
5 wooden bowls.
11 shoeing boxes.
11 braces.
599 assorted brushes.
31 assorted buckets.
15 buttresses.
21 calipers.
11 chalk lines.

122 assorted chisels.
4 carpenters' clamps.
37 saddlers' clamps.
26 claw tools.
60 clenching irons.
50 compasses.
1 countersink.
11 iron creasers.
56 wooden creasers.
62 dies.
26 die stocks.
1 set lathe drills.
2 dust pans.
72 edge tools.
2,258 files.
190 file handles.
1 square iron forge.
23 fullers.
20 saddlers' draw gauges.
5 gauges.
21 gimlets.
3 grindstones with arbors and cranks.
1 grindstone stand.
376 assorted hammers.
29 sledge hammers.
89 hammer handles.
24 hatchets.
34 hardies.
18 saddlers' horses.
1 jack screw.
408 assorted knives.
22 draw-gauge knives.
1 drawing knife.
37 splitting knives.
43 mallets.
3 tin measures.
3 nail extractors.
6,894 needles.
43 nippers.
1 standard nut.
37 oil cans.
5 oil droppers.
67 oil stones.
5 pickax handles.
90 pincers.
16 planes.
8 plane irons.
24 pliers.
8 pokers.
6 pricking carriages.
3 pricking wheels.
45 pritchels.
212 assorted punches.
70 nail punches and clench knives.
50 spring punches.
3 spring punch points.

1,171	rasps.
12	riveting irons.
44	rivet sets.
2	rounding irons.
56	rules.
66	sandstones.
29	assorted saws.
1	saw blade.
1	saw set.
1	scales.
25	scissors.
2	iron scrapers.
97	screw drivers.
12	scythes.
4	scythe snaths.
18	scythe stones.
27	shears.
12	pairs rubber shoes.
27	shovels.
4	sickles.
2	sieves.
18	sledge handles.
11	slickers.
31	pairs magazine slippers.
8	spades.
2	spokeshaves.
21	squares.
2	tin strainers.
7	tape lines.
52	taps.
11	thimbles.
18	ticklers.
99	tongs.
16	Tool handles.
1	iron tuyere.
42	vises.
54	wrenches.

APPENDIX 4.

Apportionment of ordnance, ordnance stores, &c., for the fiscal year ending June 30, 1886, under sections 1661 and 1667, Revised Statutes United States, and regulations established in conformity therewith.

States and Territories.	Number of Senators and Representatives.	Money value.
Alabama	10	$4,640 87
Arkansas	7	3,248 26
California	8	3,712 30
Colorado	3	1,392 11
Connecticut	6	2,784 22
Delaware	3	1,392 11
Florida	4	1,856 15
Georgia	12	5,568 45
Illinois	22	10,208 82
Indiana	15	6,960 56
Iowa	13	6,032 48
Kansas	9	4,176 34
Kentucky	13	6,032 48
Louisiana	8	3,712 30
Maine	6	2,784 22
Maryland	8	3,712 30
Massachusetts	14	6,496 52
Michigan	13	6,032 48
Minnesota	7	3,248 26
Mississippi	9	4,176 34
Missouri	16	7,424 59
Nebraska	5	2,320 19
Nevada	3	1,392 11
New Hampshire	4	1,856 15
New Jersey	9	4,176 34
New York	36	16,705 33
North Carolina	11	5,104 41
Ohio	23	10,672 85
Oregon	3	1,392 11
Pennsylvania	30	13,921 10
Rhode Island	4	1,856 15
South Carolina	9	4,176 34
Tennessee	12	5,568 45
Texas	13	6,032 48
Vermont	4	1,856 15
Virginia	12	5,568 45
West Virginia	6	2,784 22
Wisconsin	11	5,104 41
Alaska Territory*	3	1,392 11
Arizona Territory*	3	1,392 11
Dakota Territory*	3	1,392 11
Idaho Territory*	3	1,392 11
New Mexico Territory*	3	1,392 11
Montana Territory*	3	1,392 11
Utah Territory*	3	1,392 11
Washington Territory*	3	1,392 11
Wyoming Territory*	3	1,392 11
District of Columbia*	3	1,392 11
Total	431	200,000 00

* Apportionment according to the first paragraph of the President's regulation of April 30, 1855.

APPENDIX 5.

Statement of ordnance, ordnance stores, &c., distributed to the militia from July 1, 1885, *to June* 30, 1886, *under sections* 1661 *and* 1667, *Revised Statutes United States.*

CLASS I.

4 3-inch wrought-iron guns.
20 Gatling guns, 10 barrels, long, caliber .45″.

CLASS II.

3 carriages and limbers for 3-inch guns.
7 metallic carriages and limbers for Gatling gun, caliber .45″.
13 carriages and limbers for Gatling gun, caliber .45″.
1 12-pounder prairie carriage and limber.

CLASS III.

12 fuze blocks.
12 fuze cutters.
12 fuze gouges.
12 fuze wrenches.
2 front sights, for 3-inch rifle.
28 gunners' haversacks.
40 gunners' gimlets.
22 gunners' pincers.
39 handspikes, trail.
48 lanyards.
46 priming wires.
10 prolonges.
12 poles.
10 pole pads.
22 paulins, 12 by 15 feet.
13 pendulum hausses.
7 pendulum hausse seats.
11 pendulum hausse pouches.
47 sets artillery harness, 2 horses, lead.
47 sets artillery harness, 2 horses, wheel.
7 sponge buckets, iron.
12 sponges and rammers, 12-pounder gun.
6 sponges and rammers, 12-pounder mountain howitzer.
2 sponges and rammers, 6-pounder gun.
40 sponges and rammers, 3-inch rifle.
2 sponge covers, 6-pounder gun.
12 sponge covers, 3-inch rifle.

68 thumbstalls.
9 tar buckets, iron.
27 tube pouches.
18 tow hooks.
14 tompions.
22 vent covers.
26 vent punches.
12 vent pieces.
10 worms and staves.
36 watering buckets.
1 wheel, No. 1.

IMPLEMENTS FOR GATLING GUN.

21 gun covers.
6 clamps for worm gear.
100 feed cases.
68 feed magazines.
30 handspikes.
6 lock screw drivers.
6 small screw drivers.
6 T screw drivers.
6 shell drivers.
6 wiping rods.
6 adjusting screw wrenches.
6 pin wrenches.
6 rear-guard nut wrenches.
13 sight cases.
19 oilers.
19 hammers, riveting.
19 screw wrenches.

CLASSES IV AND V.

50 3-inch shot, fully prepared.
50 3-inch shell, fully prepared.
200 3-inch case shot.
100 3-inch canister.
200 3-inch Hotchkiss shell, time fuze.
100 12-pounder shell.
50 12-pounder shot, fixed.
50 12-pounder shell, filled.

CLASS VI.

4,554 Springfield rifles, caliber .45″.
150 Springfield "cadet" rifles, caliber .45″.
190 Springfield carbines, caliber .50″.
20 Hotchkiss magazine rifles, caliber .45″.
240 Spencer repeating shotguns.
400 Colt's revolvers, caliber .45″.
264 officers' swords.
20 non-commissioned officers' swords.
8 musicians' swords.
155 sabers, light artillery.
400 sabers, light cavalry.
583 bayonets.

CLASS VII.

APPENDAGES.

929	combination screw drivers.
379	headless shell extractors.

HORSE EQUIPMENTS.

116	curb bridles, cavalry.
2	curb bits, cavalry.
16	halters.
66	pairs spurs and straps.
116	cavalry saddles.
256	artillery saddle blankets.
406	cavalry saddle blankets.
6	pairs saddle bags.

INFANTRY EQUIPMENTS.

10,300	bayonet scabbards.
4,000	blanket bags.
3,800	pairs blanket-bag shoulder straps.
3,800	pairs coat straps.
3,700	canteens and straps.
979	cartridge belts and plates.
8,686	cartridge boxes.
4,674	gun slings.
4,700	haversacks and straps.
8,374	waist belts and plates.
430	waist belts.
3,000	meat cans.

ARTILLERY EQUIPMENTS AND PARTS.

4	leg guards.
6	linchpins, No. 1.
6	linch washers, No. 1.
32	whips.

CAVALRY EQUIPMENTS.

190	carbine slings.
190	carbine sling swivels.
337	pistol holsters.
995	saber belts and plates.
110	saber knots.

CLASS VIII.

2,200	blank cartridges, 6-pounder gun.
1,150	blank cartridges, 3-inch rifle.
551,000	rifle ball cartridges, caliber .50″.
843,000	rifle ball cartridges, caliber .45″.
57,000	rifle blank cartridges, caliber .50″.
370,000	rifle blank cartridges, caliber .45″.
34,000	revolver ball cartridges, caliber .45″.

9,000	revolver blank cartridges, caliber .45".
44,500	friction primers.
5,000	rifle shells.
130,000	cartridge primers.
80,000	rifle bullets, lubricated.
500	pounds cannon powder.
500	pounds mortar powder.

MISCELLANEOUS.

379	wiping rods, wooden.
3,400	paper targets.
6	boxes cleaning material.
30	metallic pistol grips.
6	axes, felling.
3	pickaxes, handled.
4	shovels.

PARTS OF SPRINGFIELD RIFLE, CALIBER .45".

20	bayonet clasp screws.
5	breech blocks.
5	breech screws.
240	breech-block caps.
615	breech-block cap screws.
270	bridles.
240	bridle screws.
216	cam latches.
650	cam-latch springs.
520	ejector springs.
510	ejector-spring spindles.
200	ejector studs.
350	extractors.
2,450	firing pins.
800	firing-pin screws.
500	firing-pin springs.
10	guard screws.
11	hammers.
70	hinge pins.
225	lower bands.
350	main springs.
200	main-spring swivels.
200	main-spring swivel rivets.
150	rear sights.
10	rear-sight base screws.
66	ramrods.
40	sears.
300	sear springs.
20	sear screws.
235	side screws.
60	side-screw washers.
94	spring vises.
54	stocks.
510	tumblers.
276	tumbler punches.
760	tumbler screws.

200 tang screws.
156 thumb pieces.
10 triggers.
12 upper bands.
300 front sights.
100 front-sight pins.
230 front-sight covers.
130 front-sight cover screws.
1 lock.
10 tips.
10 tip screws.
10 guards.
2 receivers.

PARTS OF SPRINGFIELD RIFLE, CALIBER .50″.

10 locks.
50 ramrods.

APPENDIX 6.

***Statement of ordnance, ordnance stores, &c., distributed to the Territories and States bordering thereon from July* 1, 1885, *to June* 30, 1886, *under the joint resolutions of July* 3, 1876, *March* 3, 1877, *and June* 7, 1878, *and the act of May* 16, 1878.**

293	Sharps carbines, caliber .50″.
600	leather bayonet scabbards.
293	carbine slings and swivels.
893	cartridge boxes.
893	waist belts and plates.
20,000	rifle-ball cartridges, caliber .50″.
50,000	carbine-ball cartridges, caliber .50″.

APPENDIX 7.

Statement of ordnance and ordnance stores, &c., distributed to colleges from July 1, 1885, to June 30, 1886, under section 1225, Revised Statutes United States, as amended by act approved July 5, 1876.

CLASS I.

4 3-inch wrought-iron rifled guns, model 1861.

CLASS II.

4 carriages and limbers for 3-inch guns.
1 caisson and limber for 3-inch gun.

CLASS III.

4 gunners' haversacks.
4 handspikes, trail.
10 lanyards.
6 priming wires.
6 paulins, 12 by 15 feet.
2 pendulum hausses.
2 pendulum hausse seats.
2 pendulum hausse pouches.
8 sponges and rammers for 3-inch gun.
10 sponge covers for 3-inch gun.
4 tompions.
10 thumbstalls.
4 tube pouches.
6 vent covers.

CLASS VI.

620 Springfield cadet rifles, caliber .45".

CLASS VII.

623 bayonet scabbards.
623 cartridge boxes.
637 waist belts and plates.
20 waist-belt plates.

CLASS VIII.

300 blank cartridges for 12-pounder gun.
300 blank cartridges for 10-pounder gun.
500 blank cartridges for 6-pounder gun.

1,400	blank cartridges for 3-inch gun.
25,000	carbine ball cartridges, caliber .45".
27,000	carbine blank cartridges, caliber .45".
3,000	carbine ball cartridges, caliber .50".
5,000	carbine blank cartridges, caliber .50".
7,800	friction primers.

PARTS OF SPRINGFIELD RIFLES.

100	screw drivers.
9	spring vises.
15	tumbler punches.
1	stock, Springfield rifle, caliber .50".
2	hammers, Springfield rifle, caliber .50".
2	ramrods, Springfield rifle, caliber .50".
9	bayonets, Springfield rifle, caliber .50".

APPENDIX 8.

SHOWING STATIONS AND DUTIES OF THE OFFICERS OF THE ORDNANCE DEPARTMENT ON OCTOBER 1, 1886.

Rank and name.	Duty.	Address.
BRIGADIER-GENERAL.		
Stephen V. Benét	Chief of Ordnance	Washington, D. C.
COLONELS.		
1. J. McAllister, brevet	Commanding the New York Arsenal, president of the Ordnance Board, and president of Board for Testing Rifled Cannon, &c.	Governor's Island, New York City. Post-office box 1449.
2. S. Crispin, brevet	Commanding the Benicia Arsenal	Benicia, Cal.
3. T. G. Baylor, brevet	Commanding the Rock Island Arsenal.	Rock Island, Ill.
LIEUTENANT-COLONELS.		
1. J. M. Whittemore	Commanding the Watervliet Arsenal	West Troy, N. Y.
2. A. R. Buffington	Commanding the National Armory	Springfield, Mass.
3. D. W. Flagler, brevet	Commanding the Frankford Arsenal	Philadelphia, Pa.
4. A. Mordecai, brevet	Member of the Ordnance Board and member of Board for Testing Rifled Cannon, &c.	Governor's Island, New York City. Post-office box 1449.
MAJORS.		
1. F. H. Parker, brevet	Commanding the Watertown Arsenal, and member of Board for Testing Rifled Cannon, &c.	Watertown, Mass.
2. J. P. Farley	Commanding the United States Powder Depot.	Dover, N. J.
3. L. S. Babbitt	Commanding the Fort Monroe Arsenal.	Fort Monroe, Va.
4. W. A. Marye	Assistant, National Armory	Springfield, Mass.
5. I. Arnold, jr	Commanding the San Antonio Arsenal.	San Antonio, Tex.
6. C. Comly	Commanding the Indianapolis Arsenal.	Indianapolis, Ind.
7. J. R. McGinness, brevet	Assistant, Rock Island Arsenal	Rock Island, Ill.
8. G. W. McKee, brevet	Commanding the Allegheny Arsenal	Pittsburgh, Pa.
9. F. H. Phipps	Commanding the Kennebec Arsenal	Augusta, Me.
10. J. W. Reilly	Commanding the Augusta Arsenal	Augusta, Ga.
CAPTAINS.		
1. J. A. Kress, brevet major	Commanding the Saint Louis Powder Depot.	Jefferson Barracks, Mo.
2. O. E. Michaelis, brevet	Assistant, Watervliet Arsenal	West Troy, N. Y.
3. C. E. Dutton	On duty under the Interior Department.	Geological Survey, Washington, D. C.
4. J. G. Butler	Assistant, National Armory	Springfield, Mass.
5. C. Bryant	Assistant, Benicia Arsenal	Benicia, Cal.
6. A. L. Varney	Assistant, Rock Island Arsenal	Rock Island, Ill.
7. J. C. Clifford	Assistant, Frankford Arsenal	Philadelphia, Pa.
8. J. E. Greer	Commanding the Fort Leavenworth Ordnance Depot, and chief ordnance officer Department of the Missouri.	Fort Leavenworth, Kans.
9. J. Pitman	Commanding the Fort Abraham Lincoln Ordnance Depot, and chief ordnance officer Department of Dakota.	Fort Abraham Lincoln, Dak.
10. C. Shaler	Member of the Ordnance Board, and member of Board for Testing Rifled Cannon, &c.	Governor's Island, New York City. Post-office box 1449.
11. H. Metcalfe	Instructor of ordnance and gunnery U. S. Military Academy.	West Point, N. Y.
12. W. S. Starring	Commanding the Cheyenne Ordnance Depot, and chief ordnance officer Department of the Platte.	Cheyenne, Wyo.
13. C. S. Smith	Principal assistant in the Ordnance Bureau.	Washington, D. C.
14. S. E. Blunt (lieut. col.)	Aide-de-camp to the Lieutenant-General, and inspector of rifle practice at the Headquarters of the Army.	Washington, D. C.

STATIONS AND DUTIES OF OFFICERS, &c.—Continued.

Rank and name.	Duty.	Address.
CAPTAINS—continued.		
15. F. Heath	Assistant, Watervliet Arsenal	West Troy, N. Y.
16. D. M. Taylor	On special duty in the office of the Adjutant-General.	Washington, D. C.
17. D. A. Lyle	On foundry duty, and member of the Board on Life-saving Apparatus, &c., under the Secretary of the Treasury, and member of Board for Testing Rifled Cannon, &c.	Boston, Mass. P. O. box 2253.
18. J. Rockwell, jr	Assistant, Rock Island Arsenal	Rock Island, Ill.
19. J. C. Ayres	Assistant, Benicia Arsenal	Benicia, Cal.
20. M. W. Lyon	Assistant, Watertown Arsenal	Watertown, Mass.
21. C. W. Whipple	Assistant to the Ordnance Board	Governor's Island, New York City. Post-office box 1449.
22. A. H. Russell	Commanding the Vancouver Barracks Ordnance Depot, and chief ordnance officer, Department of the Columbia.	Vancouver, Wash.
23. R. Birnie, jr	On duty in the Office of the Chief of Ordnance.	Washington, D. C.
24. I. MacNutt	Assistant, Frankford Arsenal	Philadelphia, Pa.
25. C. C. Morrison	Assistant, Watertown Arsenal	Watertown, Mass.
26. F. Baker	Assistant, Frankford Arsenal	Philadelphia, Pa.
FIRST LIEUTENANTS.		
1. O. B. Mitcham	Assistant instructor of ordnance and gunnery, U. S. Military Academy.	West Point, N. Y.
2. H. D. Borup	On foundry duty	Boston, Mass. Post-office box 2253.
3. L. L. Bruff	On foundry duty	Cold Spring, N. Y.
4. C. H. Clark	Assistant, National Armory	Springfield, Mass.
5. W. M. Medcalfe	Assistant to the Ordnance Board	Governor's Island, New York City. Post-office box 1449.
6. William Crozier	Assistant, Watertown Arsenal	Watertown, Mass.
7. W. B. Gordon	Instructor of philosophy, U. S. Military Academy.	West Point, N. Y.
8. F. E. Hobbs	On foundry duty	Station G, Philadelphia, Pa.
9. D. A. Howard	On foundry duty	Cold Spring, N. Y.
10. S. E. Stuart	Instructor of philosophy, U. S. Military Academy.	West Point, N. Y.
ORDNANCE STOREKEEPERS.		
Captains.		
A. S. M. Morgan	On duty, Allegheny Arsenal	Pittsburgh, Pa.
W. H. Rexford	On duty, Indianapolis Arsenal	Indianapolis, Ind.
D. J. Young	On duty, Watervliet Arsenal	West Troy, N. Y.
M. J. Grealish	On duty, Augusta Arsenal	Augusta, Ga.
V. McNally	On duty in the Office of the Chief of Ordnance.	Washington, D. C.

Appendix 9.

REPORT ON THE 8-INCH YATES BREECH-LOADING RIFLE BY THE "BOARD FOR TESTING RIFLED CANNON, ETC.," APPOINTED UNDER THE ACT OF JULY 5, 1884.

(5 plates.)

This gun was transferred to the "Board for Testing Rifled Cannon, &c.," for test, by instruction from the Chief of Ordnance, U. S. Army, dated February 3, 1885.

September 18, 1885, the Board made a progress report covering the first 16 rounds fired from this gun. (See Appendix No. 48, page 48, Report of Chief of Ordnance, U. S. A., for 1885.)

The Yates rifle is a conversion from 10-inch Rodman smooth-bore gun No. 182 (West Point foundry), by lining with a Nashua steel tube, attaching a cast-iron extension piece to the muzzle of the casing and applying the Yates breech mechanism of Midvale steel. For the detailed description of the gun, dimensions, weights, &c., the Board respectfully refers to the construction report of the 8-inch Yates rifle, made by the Inspector of Ordnance at Boston, Mass.

General Description.

THE CAST-IRON BODY.

The body or casing consists of the 10-inch Rodman smooth-bore gun above mentioned, pierced through the breech and lengthened by screwing a cast-iron extension piece on the muzzle. The portion in rear of the trunnions is turned off, and circumferential grooves are cut in the exterior to receive corresponding interlocking fillets on the breech-clamps. The bottom of these annular grooves form cylindrical surfaces 28 inches in diameter. The diameters of the projecting annular fillets or recoil shoulders on the body are as follows: The rear one 29.9 inches, the two forward shoulders 30 inches. The planes of the bearing surfaces of these shoulders are perpendicular to the axis of the piece. The longitudinal sections of the projecting annular fillets are trapezoidal. The radius of the breech is 34 inches; and the spherical zone tangent to and connecting the breech with the cylindrical body has a radius of 11 inches. (See Plate I, Figs. 1 and 2.)

THE STEEL TUBE.

The tube is made of Nashua (N. H.) steel, is cylindrical on the exterior, and has a cylindrical shoulder near the rear end. It is retained

by a securing pin on the under side, placed 3 feet 6 inches in front of the axis of the trunnions.

The chamber and rifled portion of the bore are concentric. The chamber has 3 conical and 2 cylindrical surfaces. The rear end of the chamber is recessed for the insertion of the gas-check by a counterbore .45 inches in depth. The rear conical surface is 11.7 inches in length and extends forward from the bottom of the counterbore, and is intended to support the walls of the long "cartridge head" or gas check, and to facilitate its removal.

A vertical slot is cut below the axis of the chamber and in the rear end of the tube to permit the use of an extractor in case the gas check sticks in its seat.

THE BREECH CLAMPS.

These two clamps are made of Midvale steel. They are symmetrical, cylindrical, and rounded in rear. The clamps embrace the breech of the casing like a shell, and are pivoted and held together by two assembling bolts, one screwed into the upper surface of the casing, and the other into the lower or under surface. The interior surface of the clamps corresponds to the exterior surface of the casing before described. Grooves are cut in this surface to correspond with the annular fillets on the exterior of the casing.

The axial portion of the interior surface of the clamps receives the pressure exerted upon the "cartridge head" or gas check and transmits it through the cylindrical walls of the clamps to the recoil shoulders on the cast iron casing.

THE CAM LEVER.

This is intended to operate the breech mechanism and is pivoted beneath the body of the gun. It has two curved cam slots, one on each side of the pivot, which engage the cam pins attached to the two breech clamps. The lateral swing permitted by these slots is sufficient to expose the rear end of the chamber for the purpose of loading.

THE LATCH.

The original locking device was a hooked lever attached to one clamp above the center of the breech, which caught upon a pin in the other clamp when the mechanism was closed. It was furnished with a flat retaining spring of steel.

THE FIRING DEVICE.

This consisted of a hammer actuated by a lanyard and a firing pin. A spiral firing-pin spring was inserted to retract the firing pin after the discharge of the piece. Instead of a friction or other primer, a 22-inch caliber pistol cartridge was designed to ignite the charge.

VENTING.

A radial vent was placed in the "cartridge head" or gas check to receive the priming cartridge which was exploded by the axial firing pin seated in a cylindrical lug in one of the breech clamps.

The above-described firing device and vent were abandoned after the sixteenth round, and an ordinary radial vent was inserted 10 inches in front of the bottom of the chamber.

ORIGINAL GAS CHECK.

This gas check was made of composition metal or bronze, and was called the "cartridge head" by the inventor. Its exterior form was similar to the metallic cases of small-arm cartidges. The exterior of the head corresponds in curvature to the breech of the gun. The bottom on the interior was hemispherical, with a radius of 4 inches. It had an axial vent bushed in rear with a steel disk.

PRINCIPAL DIMENSIONS.

	Inches.
Total length of gun	168
Total length of bore	160
Diameter of bore	8
Length of rifled portion of bore (original)	135.25
Total length of chamber (original)	24.75
Length of rifled portion of bore (after 16th round)	133.25
Total length of chamber (after 16th round)	26.75
Breech clamps (two):	
Thickness of metal:	
At bottom	8
At shoulders	2.5
At 1st groove	1.53
At 2d groove	1.58
At 3d groove	1.75
Radius of breech:	
Exterior (bore)	32
Interior (bottom)	34

Number of recoil shoulders (casing and clamps), 3 each.

WEIGHTS.

	Pounds.
Total weight of gun	18,540
Weight of clamps	3,452
Weight of "cartridge head," or original gas check	48.5
Preponderance—muzzle	327

RIFLING.

The rifling is polygroove, with an equal number of lands and grooves.

Number of grooves		45
Grooves:		
Width	inches	0.3884
Depth	do	0.06
Bottom rounded with radius of	do	0.06
Lands:		
Width	do	0.17
Rounded with radius of	do	0.01
Twist, uniform, one turn in	feet	30

ELONGATION OF BREECH CLAMPS.

From data furnished by Colonel Yates, the metal of the clamps possessed the following physical properties, viz:

Number of casting.	Elongation.	Elastic limit (pounds per square inch.)	Tenacity (pounds per square inch.)
	Per cent.		
4176	6.5	41,750	83,500
4219	8.5	43,671	87,343

The marks left upon the head of the gas check in the early firings indicated that one of the clamps yielded more than the other. At the fourth round the right clamp alone was found to be bearing properly; the left clamp was found to be bearing at the end of the seventh round.

PRESENCE OF INVENTOR.

The inventor, Colonel Yates, was allowed to be present during the trials, and to make whatever changes he desired in the gas check, vent, or breech mechanism upon the approval of the Chief of Ordnance, U. S. Army, and to make *any* changes he desired when done at his own expense.

EXPERIMENTS.

These were all made at the Ordnance Proving Ground, at Sandy Hook, New Jersey.

AMMUNITION.

The 8-inch Hotchkiss projectiles and Du Pont's hexagonal powders E. V. L. and E. V. K., density 1.750 and granulation 72, were employed in all the firings.

ENDURANCE TEST.

The Board decided upon firing 500 rounds, with 35 pounds of powder and 180-pound projectiles, as a test for endurance.

STAR GAUGING.

The gun was star gauged after the 5th, 8th, 16th, 26th, 59th, 114th, 154th, 220th, and 259th rounds.

ALTERATIONS.

Vent.—After the 16th round a radial vent was inserted in the vertical plane through axis of bore and on top of the piece to replace the axial vent in the breech.

Chamber.—This was lengthened 2 inches at the same time the vent was changed.

Locking device.—The flat retaining spring broke at the 6th round. After the 10th round a new and heavier locking catch of steel was substituted for the original one. After the 13th round the steel locking catch was replaced by one of wrought iron 1.25 inches thick and 5 inches wide, fitting over two 2.25-inch steel pins. After the 14th round a new locking plate and a new pin on the right clamp were put in. After the 16th round, the latching devices for locking the breech clamps being unsatisfactory to the inventor, he replaced the latches and pins by a steel cap with a retaining device for keeping it closed. (Plate I, Fig. 3.) A cylindrical tenon, 1.5 inches long and 12 inches in diameter, one-half upon rear of each clamp, was turned, over which a rounded cylindrical cap, about 12 inches interior diameter and 18 inches exterior diameter, was fitted. This cap was hinged to one clamp and latched to the other. The other changes were made at the request of the inventor, under his supervision, and in accordance with his letter (Ordnance Office, No. 104 I, of 1885). In a letter dated September 25, 1885, the in-

ventor, Colonel Yates, says, in relation to this cap over the rear end of the clamps:

It is rather awkward to manipulate, and it takes as much time to free it as it does to open and close the sections.

The clamp employed was suggested by me, but has nothing to do with the system; is peculiar to this gun, and would not be used on another. * * * In firing for rapidity, I do respectfully ask that the Board will give the above facts due consideration. * * *

GAS CHECKS.

Several gas checks were employed during the course of the experiments. Below will be found a brief sketch of these obturators:

No. 1. Original gas check or "cartridge head." (Plate II, Fig. 1.)—This was made of composition metal or bronze, and has already been sufficiently described. Its principal dimensions are as follows:

Total length	inches..	12.00
Length of body	do....	11.25
Diameter, exterior:		
Front end	do....	8.25
Rear end	do....	8.67
Head	do....	9.25
Radius of base-exterior	do....	34.00
Interior:		
Total length	do....	11.00
Diameter, conical part, front base	do....	8.05
rear base	do....	8.00
Radius of bottom	do....	4.00
Thickness of metal, front end	do....	0.10
at bottom (on axis)	do....	1.00
Weight	pounds..	48.50

After the 2d round, one-sixteenth-inch was turned off the lip and the exterior surface was turned off slightly; after the 3d round another one-sixteenth inch was taken off the lip and the surface was eased as before; after the 4th, 5th, and 6th rounds the exterior was filed slightly to make it fit the chamber easily. Number of rounds fired, 7.

Gas check No. 2 (Plate II, Fig. 2).—This was No. 1 gas check cut off to 6 inches in length and the hemispherical interior turned out to cup shape, with the exterior reduced by filing. Number of rounds employed, 1 (No. 8).

Gas check No. 3.—Steel gas check, 9 inches long; used for firing rounds 9 to 13, inclusive, 5 rounds.

Gas check No. 4 (Plate II, Fig 3).—A compound gas check, consisting of a copper cup pinned to a steel base; used from the 14th to the 124th rounds, inclusive, 111 rounds. Before firing the 60th round the lip of the copper ring was shortened eleven-sixteenths inch and the rim on the steel head filed circumferentially. Gas check readjusted before the 98th, 100th, and 102d rounds.

Gas check No. 5 (Plate II, Fig. 4).—Steel gas check substituted for compound one. During the firing of this gun the gas check was removed, washed on exterior with wet cotton waste, and then wiped with oiled waste. The seat in the gun was wiped out after each round. This check was used from the 125th to the 220th rounds, inclusive, 96 rounds.

Gas check No. 6 (Plate II, Fig. 5).—New steel gas check. It was inserted and removed easily with the hook before firing. Stuck after firing, and removed with considerable difficulty with a lever. Examination showed a slight distortion of gas check due to eccentricity in the seat. Used during 1 round (the 221st).

Gas check No. 7 (same form as No. 6).—Aluminum bronze gas check. Seat for gas check reamed out so as to increase pitch 0.1 inch on a side. After the 241st round a defect was discovered presenting a honey-combed appearance, through which water percolated; the lip was beveled. During the firing with this check it was necessary to wash and scrape the bearing surface after each round, as well as to clean and wipe the seat with oiled waste. The bearing surface of the gas check was generally smeared with remnants of cartridge bag and powder residue. This check was used from the 222d to the 269th rounds, inclusive; in all, 48 rounds. Of these 48 rounds, in only 14 rounds, or 29 per cent., was the check removed from its seat after firing without difficulty; in the other 71 per cent. of the rounds more or less difficulty was experienced in extracting the gas check.

Gas check No. 8.—Aluminum bronze check, with lip beveled—same as No. 7, after the modification made before the 242d round, but a more perfect casting. After round No. 271 incipient cracks were observed over the inner surface of the check, and the gas check was difficult to remove. Two rounds were fired with this check, Nos. 270 and 271.

Gas check No. 9 (Plate II, Fig. 6).—New steel gas check, consisting of a steel ring fastened to a steel base by six pins passing through thin steel and copper plates. After the 273d round a piece of sheet tin was inserted in rear of upper side of check. Gas check dismounted after 272d round, and it was found that gas had entered all the joints, though not to any serious extent. This gas check was used from rounds 272 to 281, inclusive; in all, 10 rounds. In 4 rounds only was it removed without difficulty.

Gas check No. 10 (Plate II, Fig. 7).—New gas check; copper cup pinned to steel base and marked "C"; weight, 26 pounds. At the second round fired with it the steel was found to be set out, and the pins were loosened. Marks of gas escape. Two rounds fired with this gas check, Nos. 282 and 283.

Gas check No. 11—This is the same as No. 9, except that the steel ring is replaced by a copper ring. It was marked "R," and weighs 33.25 pounds. The extractor hooks used to remove the gas check weigh 13 pounds. The check did not produce perfect obturation. It was removed easily except in first two rounds, when but slight difficulty was found in extracting it. This gas check was employed during 29 rounds, from the 284th to the 312th rounds. At the 312th round the gun burst explosively. Plate III, shows the position after rupture of the principal fragments.

THE YATES BREECH MECHANISM.

This system of breech fermeture consists of: (1) two steel breech clamps; (2) gas check; (3) cam lever; (4) locking device for breech.

The steel breech clamps and the gas check are the essential features of the system, and cannot be divorced in its consideration, as without the gas check the clamps are useless and impracticable.

The clamps are of steel, and having different degrees of elongation, it is difficult to have them sustain equal pressures at the same time, as one may yield more than the other.

The gas check is unattached to the mechanism, which of itself is an objectionable feature, as it requires removal after each round. In this manipulation it is liable to injury from dropping or striking against objects. Its weight for this gun has varied from 26 to 48.5 pounds. For larger calibers it would necessarily possess *greater* weight and be more difficult to handle.

When subjected to direct or slightly inclined fire, the breech mechanism is exposed all the time to its effect.

The latching or locking devices used at first were not sufficient to hold the clamps together in firing.

The steel cap put over the tenon cut on the rear end of the clamps after the 16th round was the only successful locking device used on this gun, but it is rejected by the inventor in his letter before cited as not being intended for adoption with his system.

RESULTS OF FIRING.

1. *Number of rounds fired.*

The total number of rounds fired was 312. The gun burst explosively at the last or 312th round. The details of the firing will be found in the firing record and table of enlargements appended to this report. Appendix 48, Report of Chief of Ordnance for 1885, page 483 *et seq.*, contains the firing record for the first 16 rounds.

2. *Velocities and pressures.*

The following table records the velocities and pressures taken since the previous report:

VELOCITIES AND PRESSURES.

[*Gun:* Eight-inch Yates breech-loading rifle, lined with Nashua (N. H.) steel tube. *Projectile:* Eight-inch Hotchkiss; weight, 181 pounds. *Powder:* Du Pont's hexagonal E. V. L.; density, 1.750; granulation, 72; charge, 35 pounds. *Instruments for velocity:* Two Le Boulengé chronographs (mean taken). *For pressure:* Crusher gauge.]

Date.	No. of fire.	Initial velocity.		Pressure per square inch.	Recoil.
		Distance from muzzle.	Feet per second.		
					Feet.
September 24, 1885	18	At 108 feet from muzzle.	1,493	31,100	4.67
Do	19		1,495	32,150	4.50
Do	20		1,504	33,450	4.50
Do	21		1,512	34,600	4.50
Do	22		1,506	32,750	4.50
Do	23		1,502	33,000	4.50
Do	24		1,489	30,550	4.50
Do	25		1,495	31,400	4.50
Do	26		1,502	32,500	4.50
Mean of 9 rounds			1,499.7+	32,388.8	4.52
September 25, 1885	32	108′ 2″	1,493	29,300	4.50
Do	34	108′ 2″	1,484	29,750	4.50
Mean of 2 rounds			1,488.5	29,525	4.50

The following table gives the additional pressures taken, without observing the velocities.

PRESSURES.

With 180-pound Hotchkiss projectiles.

Date.	No. of fire.	Pressure per square inch.	Recoil.	Remarks.
			Feet.	
September 30, 1885	37	33, 050	4. 50	E. V. L.; density, 1.750; granulation, 72.
Do	38	32, 200	4. 50	Do.
Do	39	34, 100	4. 50	Do.
Do	40	34, 750	4. 50	Do.
Do	41	32, 300	4. 50	Do.
Do	42	29, 850	4. 50	Do.
Do	43	30, 450	4. 50	Do.
Do	44	32, 950	4. 50	Do.
February 17, 1886	228	27, 700	3. 92	Do.
Do	229	28, 750	3. 92	Do.
Do	231	29, 650	3. 92	Do. 37 pounds this round.
March 10, 1886	272	32, 400	4. 00	E. V. K.; density, 1.750; granulation, 72.
Do	273	32, 100	4. 00	Do.
Mean of 13 rounds	....	31, 557. 7	4. 28+	

With 181-pound Hotchkiss projectile.

September 25, 1885	33	28, 500	4. 50	E. V. L.
Do	36	30, 800	4. 50	E. V. L.
Mean of 2 rounds	....	29, 650	4. 50	

With 182-pound Hotchkiss projectile.

February 18, 1886	242	28, 700	3. 96	E. V. K.
Do	243	31, 650	3. 96	Do.
Mean of 2 rounds	....	30, 175	3. 96	

The pressures and velocities were normal; the maximum pressure of 35,000 pounds per square inch, prescribed for eight converted guns, was only exceeded once, in the 16th round, when it reached 39,775 pounds per square inch. The mean velocity was about 1,500 feet per second.

3. *Enlargement of the bore.*

This is found to be very uniform and not excessive. The gun was not star gauged during the last 55 rounds; it was the intention to star gauge after the 315th round, but the gun burst before that limit was reached.

Below is given a table of enlargements at the last star gauging. These enlargements do not take into account the *play* of the tube, which would diminish them by 0.003 inch.

Table showing enlargement of bore after 257 rounds, as shown by star gauge.

[Total length of bore, 160 inches; length of rifled portion (original), 135.25 inches; total length of chamber (original), 24.75 inches; length of rifled portion (after 16th round), 133.25 inches; total length of chamber (after 16th round), 26.75 inches; play between tube and casing, 0.003 inch.]

Inches from muzzle.	Original diameter.	Diameter after 257 rounds.	Enlargement.	Inches from muzzle.	Original diameter.	Diameter after 257 rounds.	Enlargement.	Inches from muzzle.	Original diameter.	Diameter after 257 rounds.	Enlargement.
133	8.004	8.031	0.027	101	8.003	8.010	0.007	58	8.001	8.004	0.003
132	8.004	8.029	0.025	100	8.003	8.010	0.007	56	8.001	8.005	0.004
131	8.004	8.026	0.022	99	8.003	8.009	0.006	54	8.001	8.005	0.004
130	8.004	8.024	0.020	98	8.003	8.009	0.006	52	8.001	8.005	0.004
129	8.003	8.023	0.020	97	8.003	8.009	0.006	50	8.000	8.005	0.005
128	8.003	8.021	0.018	96	8.003	8.009	0.006	48	8.000	8.005	0.005
127	8.003	8.020	0.017	95	8.003	8.008	0.005	46	8.001	8.005	0.004
126	8.003	8.020	0.017	94	8.003	8.008	0.005	44	8.001	8.005	0.004
125	8.003	8.019	0.016	93	8.003	8.008	0.005	42	8.001	8.005	0.004
124	8.003	8.018	0.015	92	8.002	8.008	0.006	40	8.002	8.005	0.003
123	8.003	8.017	0.014	91	8.002	8.008	0.006	38	8.002	8.005	0.003
122	8.003	8.017	0.014	90	8.002	8.008	0.006	36	8.002	8.005	0.003
121	8.003	8.016	0.013	89	8.002	8.008	0.006	34	8.002	8.005	0.003
120	8.003	8.015	0.012	88	8.002	8.008	0.006	32	8.002	8.005	0.003
119	8.003	8.015	0.012	87	8.002	8.008	0.006	30	8.003	8.005	0.002
118	8.003	8.014	0.011	86	8.002	8.008	0.006	28	8.004	8.005	0.001
117	8.003	8.014	0.011	85	8.002	8.008	0.006	26	8.004	8.006	0.002
116	8.003	8.014	0.011	84	8.002	8.008	0.006	24	8.005	8.007	0.002
115	8.003	8.014	0.011	83	8.002	8.007	0.005	22	8.005	8.007	0.002
114	8.003	8.013	0.010	82	8.002	8.007	0.005	20	8.006	8.007	0.001
113	8.003	8.013	0.010	81	8.002	8.007	0.005	18	8.006	8.008	0.002
112	8.003	8.013	0.010	80	8.002	8.007	0.005	16	8.006	8.008	0.002
111	8.003	8.012	0.009	78	8.002	8.007	0.005	14	8.006	8.008	0.002
110	8.003	8.012	0.009	76	8.002	8.006	0.004	12	8.006	8.008	0.002
109	8.003	8.012	0.009	74	8.002	8.007	0.005	10	8.007	8.009	0.002
108	8.003	8.011	0.008	72	8.002	8.006	0.004	8	8.006	8.009	0.003
107	8.003	8.011	0.008	70	8.002	8.006	0.004	6	8.007	8.009	0.002
106	8.003	8.010	0.007	68	8.002	8.005	0.003	4	8.014	8.015	0.001
105	8.003	8.010	0.007	66	8.002	8.005	0.003	2	8.007	8.010	0.003
104	8.003	8.010	0.007	64	8.002	8.005	0.003	1	8.007	8.009	0.002
103	8.003	8.010	0.007	62	8.002	8.004	0.002				
102	8.003	8.010	0.007	60	8.002	8.004	0.002				

4. *Rapidity of fire.**

Number of trial.	Number of fire.		Total number of rounds.	Time required for firing.	Number of rounds fired per minute.
	From round No.—	To round No.—			
				Minutes.	
1	27	31	5	20	0.25
2	45	54	10	31	0.32
3	63	79	17	44	0.38
4	80	89	10	25	0.40
5	115	124	10	19	0.52+
6	126	135	10	18	0.55+
7	126	144	19	40	0.47+
8	115	144	30	67	0.44+
9	145	154	10	20	0.50
10	155	220	66	136	0.48
Average number of rounds fired per minute.......					0.43+

Hence, the time required to fire one round is as follows: Longest time = 4 minutes; shortest time = 1.8 minutes = 1 minute 48 seconds; average time = 2.325 minutes = 2 minutes 19½ seconds.

* This table does not include cases where gas-check or breech mechanism gave much trouble or caused considerable delay.

5. *Action of gas-checks.*

Number of check.	Number of fire.		Gas-checks.				
	From No.—	To No.—	Total rounds used.	Removed easily, No.—	Removed with more or less difficulty, No.—	Removed with rammer from muzzle, No.—	Number of rounds escape of gas noted.[1]
1	1	7	7	....	7	[2]5	....
2	....	8	1	....	1	1	....
3	9	13	5	1	4	4	....
4	14	124	111	22	89	52	[3]32
5	125	220	96	55	41	41	[4]41
6	....	221	1	....	[5]1	....	....
7	222	269	48	14	34	....	46
8	270	271	2	[6]1	1	....	2
9	272	281	10	4	6	....	10
10	282	283	2	[7]2	....	....	2
11	284	312	29	[7]2	27	....	27
Totals........			312	101	211	103	160

[1] Escape of gas through axial vent of gas-check not considered in this column.
[2] No record whether timber used or not.
[3] The last 32 rounds fired with gas-check No. 4.
[4] The last 41 rounds fired with gas-check No. 5.
[5] Removed with a pinch-bar.
[6] No remark.
[7] With little difficulty.

RECAPITULATION.

Total number of rounds fired		312
Number of rounds gas-check removed easily	101	
Number of rounds gas-check removed with more or less difficulty	211	
		312
Number of rounds in which rammer had to be used to remove gas-check		103
Number of rounds defective obturation		160

Percentages:	Rounds.
Rammer required for extraction of gas-check	33+
Gas-check extracted easily	32.4
Gas-check extracted with more or less difficulty	67.6
Defective obturation	51.28

RÉSUMÉ.

(1) The gun burst explosively at the 312th round.
(2) The velocities were normal.
(3) The pressures were normal with one exception, in the 16th round, where it reached 39.775 pounds per square inch.
(4) The enlargements of the tube were not excessive.
(5) The obturation was imperfect.
(6) The gas-checks were not satisfactory.
(7) The gas check is heavy and detachable. It is difficult to handle, and is liable to serious injury from accidental dropping or striking against objects in rapid firing.

OPINION.

As before stated, "the steel breech-clamps and the gas-check are the *essential* features of the system, and cannot be divorced in its consideration, as without the gas-check the clamps are useless and impracticable."

The gas-checks presented for this trial were detached from the mechanism, which is clumsy, inconvenient, and objectionable. This arrangement requires the removal of the gas-check after each round and exposes

it to the liability of injury from accidental dropping or striking against objects.

When subjected to direct or slightly inclined fire the Yates breech mechanism is exposed to its effects *at all times*, an objection which does not obtain with any of the principal breech fermetures now used in our own or foreign services.

From a careful study of the results of the trial with the mechanism presented, and of all the information submitted by Colonel Yates, the Board is of the opinion that the "Yates breech closing device" does not possess sufficient merit to warrant its adoption for the service of the United States.

CONCLUSION.

The 8-inch Yates breech-loading rifle has been "subjected to the proper test, including such rapid firing as a like gun would be likely to be subjected in actual battle, for the determination of the endurance of the same," and has not proved satisfactory to the Board; therefore the Board cannot recommend that it "be put to use in the Government service."

Firing record, drawings showing 8-inch Yates breech-loading rifle, gas-checks, and position of fragments after explosion, and photograph showing exploded gun, are inclosed.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
F. H. PARKER,
Major of Ordnance.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.
D. A. LYLE,
Captain of Ordnance.

After the completion of this report Colonel Yates presented to the Board a communication on the subject of his breech mechanism, which, having been submitted to all the members, is hereunto appended and marked A.

For the Board.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.

A.

NEW YORK CITY, *April* 2, 1886.

Col. T. G. BAYLOR, U. S. A.,
President Testing Board:

COLONEL: I am interested in your report only in so far as regards my breech-closing device. It has always been understood and agreed that I had no interest in the gun except as a means of testing my device. The progress report of your Board, Appendix 48, Report for 1885, of Chief of Ordnance, pertains to my device in so far only as it refers to difficulty of opening the breech and shaking apart of the jacket gear during the first 16 rounds. I explained the trouble as being, in the first case, due solely to the upsetting and wedging of the cartridge head, and, in my letter to you of May 8, 1885, claimed that the latter trouble was due to vibration, &c., and the experience in all rounds since the 16th is proof of the truth of my statements. You will do me the justice to say that I never did object to pressures, and asked to have the chamber

enlarged to "provide for increased charges, if desired," which meant *higher pressures* and a more severe test of my system. I had no reason to fear high pressures. I have always said that the breech should be the strongest part of a gun, and if mine is not so, it has no value. My device has realized all that I ever claimed for it; it worked as easily and well at the 312th as at the 1st round, and would have done as well to the 5,000th if the gun had not failed. The cartridge-heads and gas-checks used are no part of my breech-closing system. The inclosed sketch exhibits a gas-check long used and approved in Europe, is easily adapted to my system of breech-closing, and there can be no question as to its operation. I hope to prove that no gas-check, as such, is needed in my case. If instructions to your Board require reports upon the gun, and upon my cartridges or cartridge-heads, I respectfully request that the report on my "breech-loading system" may be kept distinct and independent.

The provision by Congress was to test "breech-loading devices." The provision by the Secretary of War was to test the "Yates breech-loading device." I was not permitted to make a gun, and accepted the conversion only because it was understood and agreed that the only thing on trial and to be tested was my breech-loading device.

It was so stated by me to your Board from first to last, and in my letter to the Chief of Ordnance of December 31, 1884, copy of which you have, after speaking of troubles with metal, &c., I said, "It is understood that this is to be a test of my breech-closing device, and, in order that the trial may not be delayed, I accept the gun, depending upon a fair consideration of the conditions."

I also ask that in your report you refer only to the "Yates breech-loading device," or system, not Yates gun or rifle, *which has no existence*. I ask only that my system of breech-loading be considered singly, on its merits; not burdened with matters not properly belonging to it. You will understand this only as the expression of a wish to have this matter presented as simply and fairly as may be. I have to thank your Board for the manifest disposition to do everything needful to make this test complete and satisfactory to the Government and to myself.

Very respectfully, your obedient servant,

THEO. YATES.

Record of firing with 8-inch Yates breech-loading rifle at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity, 108' from muzzle.	Recoil.
		1885.		*Lbs.*		*Lbs.*	°	*Pounds.*	*Feet.*	*Feet.*
P. M. — Barometer, 29.896; thermometer, 68.0; humidity, 68.	17	Sept. 24	Du Pont's hexagonal E. V. L. Density, 1.750; granulation, 72.	30	Hotchkiss ..	181	—30	....	....	......
	18	Sept. 24		35	Hotchkiss ..	181	—30	31,100	1,493	4.67
	19	Sept. 24		35	Hotchkiss ..	181	—40	32,150	1,495	4.50
	20	Sept. 24		35	Hotchkiss ..	181	—40	33,450	1,504	4.50
	21	Sept. 24		35	Hotchkiss ..	181	—40	34,000	1,512	4.50
	22	Sept. 24		35	Hotchkiss ..	181	—40	32,750	1,506	4.50
	23	Sept. 24		35	Hotchkiss ..	181	—40	33,000	1,502	4.50
	24	Sept. 24		35	Hotchkiss ..	181	—40	30,550	1,489	4.50
	25	Sept. 24		35	Hotchkiss ..	181	—40	31,400	1,495	4.50
	26	Sept. 24		35	Hotchkiss ..	181	—40	32,500	1,502	4.50
A. M. — Barometer, 30.229; thermometer, 65.2; humidity, 77.	27	Sept. 25		35	Hotchkiss ..	181	—40	....	....	4.50
	28	Sept. 25		35	Hotchkiss ..	181	—40	....	....	4.50
	29	Sept. 25		35	Hotchkiss ..	181	—40	....	....	4.50
	30	Sept. 25		35	Hotchkiss ..	181	—40	....	....	4.50
	31	Sept. 25		35	Hotchkiss ..	181	—40	....	....	4.50
									108'.2"	
	32	Sept. 25		35	Hotchkiss ..	181	—40	29,300	1,493	4.50
	33	Sept. 25		35	Hotchkiss ..	181	—40	28,500	Lost	4.50
	34	Sept. 25		35	Hotchkiss ..	181	—40	29,750	1,484	4.50
P. M. — Barometer, 29.989; thermometer, 71.4; humidity, 77.	35	Sept. 30		35	Hotchkiss ..	181	—40	30,200	....	4.50
	36	Sept. 30		35	Hotchkiss ..	181	—40	30,800	....	4.50
	37	Sept. 30		35	Hotchkiss ..	180	—40	33,050	....	4.50
	38	Sept. 30		35	Hotchkiss ..	180	—40	32,200	....	4.50
	39	Sept. 30		35	Hotchkiss ..	180	—40	34,100	....	4.50
	40	Sept. 30		35	Hotchkiss ..	180	—40	34,750	....	4.50
	41	Sept. 30		35	Hotchkiss ..	180	—40	32,300	....	4.50
	42	Sept. 30		35	Hotchkiss ..	180	—40	29,850	....	4.50
	43	Sept. 30		35	Hotchkiss ..	180	—40	30,450	....	4.50
	44	Sept. 30		35	Hotchkiss ..	180	—40	32,950	....	4.50
	45	Sept. 30		35	Hotchkiss ..	182	—40	....	....	4.50
	46	Sept. 30		35	Hotchkiss ..	182	—40	....	....	4.50
	47	Sept. 30		35	Hotchkiss ..	182	—40	....	....	4.50
	48	Sept. 30		35	Hotchkiss ..	182	—40	....	....	4.50
	49	Sept. 30		35	Hotchkiss ..	182	—40	....	....	4.50

Hook, N. J., from September 24, 1885, *to March* 26, 1886.

Wind—strength and direction.			Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Before firing, new locking disk fitted to breech. Vent placed at 10 inches from bottom of bore and chamber lengthened 2 inches. Copper and steel gas-check used.			
From rear and right 87°—20 miles an hour.	Fired into sand butt.	To try breech closure.	Breech opened and gas-check removed easily. No escape of gas.
			Gas-check inserted with some difficulty. Removed easily. No escape of gas. ½ gallon oil put in cylinder.
			Breech opened and gas-check removed easily. No escape of gas.
			Breech opened and gas-check removed easily. No escape of gas.
			Breech opened and gas-check removed easily. No escape of gas.
			Breech opened and gas-check removed easily. No escape of gas.
			Breech opened easily. Gas-check removed less easily. No escape of gas. Gas-check oiled.
			Breech opened easily. Gas-check (not oiled) removed easily. No escape of gas.
			Breech opened easily. Gas-check (not oiled) removed easily. No escape of gas.
			Breech opened easily. Gas-check (not oiled) removed easily. No escape of gas.
		Gun star-gauged.	
From front and left 87°—8 miles an hour.		For endurance. Right guide-bolt broke.	Fired in 20 minutes. Breech opened easily. Gas-check (not oiled) removed easily. No escape of gas.
		Before this round gas-check inserted without cartridge, and it was necessary to seat it without handspike.	
From front—11 miles an hour.	Fired into sand butt for endurance.	Fired in 31 minutes.	Gas-check removed easily.
			Gas-check removed with some difficulty.
			Rammer had to be used to remove gas-check.

Record of firing with 8-inch Yates breech-loading rifle, at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity.	Recoil.
		1885.		*Lbs.*		*Lbs.*	′	*Pounds.*	*Feet.*	*Feet.*
P. M. — Barometer, 29.989; thermometer, 71.4; humidity, 77.	50	Sept. 30	Du Pont's hexagonal E. V. L. Density, 1.750; granulation, 72.	35	Hotchkiss ..	182	—40	....	....	4.50
	51	Sept. 30		35	Hotchkiss ..	182	—40	....	....	4.50
	52	Sept. 30		35	Hotchkiss ..	182	—40	....	....	4.50
	53	Sept. 30		35	Hotchkiss ..	182	—40	....	....	4.50
	54	Sept. 30		35	Hotchkiss ..	182	—40	....	....	4.50
	55	Sept. 30		35	Hotchkiss ..	182	—40	....	....	4.50
	56	Sept. 30		35	Hotchkiss ..	182	—40	....	....	4.50
	57	Sept. 30		35	Hotchkiss ..	178	—40	....	....	4.50
	58	Sept. 30		35	Hotchkiss ..	178	—40	....	....	4.50
	59	Sept. 30		35	Hotchkiss ..	178	—40	....	....	4.50
A. M. — Barometer, 30.105; thermometer, 68; humidity, 80.	60	Oct. 1		35	Hotchkiss ..	181	—48	....	....	4.50
	61	Oct. 1		35	Hotchkiss ..	181	—48	....	....	4.50
	62	Oct. 1		35	Hotchkiss ..	181	—48	....	....	4.50
	63	Oct. 1		35	Hotchkiss ..	181	—48	....	....	4.50
	64	Oct. 1		35	Hotchkiss ..	181	—48	....	....	4.50
	65	Oct. 1		35	Hotchkiss ..	181	—48	....	....	4.50
	66	Oct. 1		35	Hotchkiss ..	181	—48	....	....	4.50
	67	Oct. 1		35	Hotchkiss ..	181	—48	....	....	4.50
	68	Oct. 1		35	Hotchkiss ..	181	—48	....	....	4.50
	69	Oct. 1		35	Hotchkiss ..	181	—48	....	....	4.50
	70	Oct. 1		35	Hotchkiss ..	181	—48	....	....	4.50
	71	Oct. 1		35	Hotchkiss ..	181	—48	....	....	4.50
	72	Oct. 1		35	Hotchkiss ..	181	—48	....	....	4.50
	73	Oct. 1		35	Hotchkiss ..	181	—48	....	....	4.50
	74	Oct. 1		35	Hotchkiss ..	181	—48	....	....	4.50
	75	Oct. 1		35	Hotchkiss ..	181	—48	....	....	4.50
	76	Oct. 1		35	Hotchkiss ..	181	—48	....	....	4.50
	77	Oct. 1		35	Hotchkiss ..	181	—48	....	....	4.50
	78	Oct. 1		35	Hotchkiss ..	181	—48	....	....	4.50
	79	Oct. 1		35	Hotchkiss ..	181	—48	....	....	4.50
	80	Oct. 1		35	Hotchkiss ..	177	—48	....	....	4.50
	81	Oct. 1		35	Hotchkiss ..	177	—48	....	....	4.50
	82	Oct. 1		35	Hotchkiss ..	177	—48	....	....	4.50
	83	Oct. 1		35	Hotchkiss ..	177	—48	....	....	4.50
	84	Oct. 1		35	Hotchkiss ..	177	—48	....	....	4.50
	85	Oct. 1		35	Hotchkiss ..	177	—48	....	....	4.50

Hook, N. J., from September 21, 1885, *to March* 26, 1886—Continued.

Wind—strength and direction.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
From front—11 miles an hour.	Fired into sand butt for endurance. Fired in 31 minutes.	Rammer had to be used to remove gas-check.
From front and left 87°—8 miles an hour.	Before round 60 gun washed out and then gauged. Lip of copper ring in gas-check shortened $\frac{1}{16}$ inch and rim on steel head filed off cicumferentially.	Gas-check removed easily.
	Fired into sand butt for endurance. Fired in 44 minutes.	Gas-check removed with some difficulty.
	Gun washed out. Fired in 25 minutes.	Rammer had to be inserted from muzzle to remove gas-check from seat.

Record of firing with 8-inch Yates breech-loading rifle, at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity.	Recoil.
		1885.		*Lbs.*		*Lbs.*	′	*Pounds.*	*Feet.*	*Feet.*
A. M. — Barometer, 30.105; thermometer, 68; humidity, 80.	86	Oct. 1	Du Pont's hexagonal E. V. L. Density, 1.750; granulation, 72.	35	Hotchkiss	177	—48	....	....	4.50
	87	Oct. 1		35	Hotchkiss	177	—48	....	....	4.50
	88	Oct. 1		35	Hotchkiss	177	—48	....	....	4.50
	89	Oct. 1		35	Hotchkiss	177	—48	....	....	4.50
P. M. — Barometer, 30.054; thermometer, 68; humidity, 79.	90	Oct. 1		35	Hotchkiss	182	—48	....	....	4.50
	91	Oct. 1		35	Hotchkiss	182	—48	....	....	4.50
	92	Oct. 1		35	Hotchkiss	182	—48	....	....	4.50
	93	Oct. 1		35	Hotchkiss	182	—48	....	....	4.50
	94	Oct. 1		35	Hotchkiss	182	—48	....	....	4.50
	95	Oct. 1		35	Hotchkiss	182	—48	....	....	4.50
	96	Oct. 1		35	Hotchkiss	182	—48	....	....	4.50
	97	Oct. 1		35	Hotchkiss	182	—48	....	....	4.50
	98	Oct. 1		35	Hotchkiss	181	—48	....	....	4.50
	99	Oct. 1		35	Hotchkiss	181	—48	....	....	4.50
	100	Oct. 1		35	Hotchkiss	180	—15	....	....	4.50
	101	Oct. 1		35	Hotchkiss	180	—15	....	....	4.50
	102	Oct. 1		35	Hotchkiss	180	—15	....	....	4.50
	103	Oct. 1		35	Hotchkiss	179	—15	....	....	4.54
	104	Oct. 1		35	Hotchkiss	178	—15	....	....	4.50
	105	Oct. 1		35	Hotckhiss	178	—15	....	....	4.50
	106	Oct. 1		25	Hotchkiss	178	—15	....	....	4.50
	107	Oct. 1		35	Hotchkiss	178	—30	....	....	4.50
	108	Oct. 1		35	Hotchkiss	177	—30	....	....	4.50
	109	Oct. 1		35	Hotchkiss	177	—30	....	....	4.50
	110	Oct. 1		35	Hotchkiss	181	—30	....	....	4.50
	111	Oct. 1		35	Hotchkiss	181	—30	....	....	4.50
	112	Oct. 1		35	Hotchkiss	181	—30	....	....	4.50
	113	Oct. 1		35	Hotchkiss	181	—30	....	....	4.50
	114	Oct. 1		35	Hotchkiss	181	—30	....	....	4.50
A. M. — Barometer, 30.031; thermometer, 59.7; humidity, 100.	115	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	116	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	117	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	118	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	119	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	120	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50

Hook, N. J., from September 24, 1885, to March 26, 1886—Continued.

Wind—strength and direction.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
From front and left 87°—8 m. an hour.	Fired in 25 minutes.	Rammer had to be inserted from muzzle to remove gas-check from seat.
	Gun washed out.	Gas-check removed with considerable difficulty.
From front and left 43°—10 miles an hour.	Fired into sand butt for endurance.	Rammer used to unseat gas-check. Slight escape of gas around head of check.
		Slight escape of gas around head of check.
		Slight escape of gas around head of check.
		Considerable escape of gas.
	Before round 98 nuts on bolts holding copper disk to steel plate tightened up.	Slight escape of gas.
		Slight escape of gas.
	Before round 100 copper head removed from check, examined, replaced, and filed over bearing surface.	Slight escape of gas.
		Gas-check removed with difficulty by extractor. Slight escape of gas.
	Left truck-wheel jarred off. Steel bearing gas-check filed down.	Rammer used to unseat gas-check. Very slight escape of gas.
	Gun star-gauged.	
From rear and left 48°—19 miles an hour.	Fired in 19 minutes.	Slight escape of gas.

Record of firing with 8-inch Yates breech-loading rifle, at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity.	Recoil.
		1885.		*Lbs.*		*Lbs.*	′	*Pounds.*	*Feet.*	*Feet.*
A. M. — Barometer, 30.031; thermometer, 59.7; humidity, 100.	121	Oct. 2	Du Pont's hexagonal E. V. L. Density, 1.750; granulation, 72.	35	Hotchkiss ..	181	—30	....	....	4.50
	122	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	123	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	124	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	125	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	126	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	127	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	128	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	129	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	130	Oct. 2		35	Hotchkiss ..	178	—30	....	....	4.50
	131	Oct. 2		35	Hotchkiss ..	178	—30	....	....	4.50
	132	Oct. 2		35	Hotchkiss ..	178	—30	....	....	4.50
	133	Oct. 2		35	Hotchkiss ..	178	—30	....	....	4.50
	134	Oct. 2		35	Hotchkiss ..	178	—30	....	....	4.50
	135	Oct. 2		35	Hotchkiss ..	177	—30	....	....	4.50
	136	Oct. 2		35	Hotchkiss ..	177	—30	....	....	4.50
	137	Oct. 2		35	Hotchkiss ..	177	—30	....	....	4.50
	138	Oct. 2		35	Hotchkiss ..	180	—30	....	....	4.50
	139	Oct. 2		35	Hotchkiss ..	180	—30	....	....	4.50
	140	Oct. 2		35	Hotchkiss ..	180	—30	....	....	4.50
	141	Oct. 2		35	Hotchkiss ..	180	—30	....	....	4.50
	142	Oct. 2		35	Hotchkiss ..	182	—30	....	....	4.50
	143	Oct. 2		35	Hotchkiss ..	182	—30	....	....	4.50
	144	Oct. 2		35	Hotchkiss ..	182	—30	....	....	4.50
	145	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	146	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	147	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	148	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	149	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	150	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	151	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	152	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	153	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	154	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50

***Hook, N. J., from September* 24, 1885, *to March* 26, 1886—Continued.**

Wind—strength and direction.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
From rear and left 48°—19 miles an hour.	Fired into sand butt for endurance. Fired in 19 minutes.	Rammer used to unseat gas-check. Slight escape of gas.
	Steel gas-check substituted for copper and steel check.	
	Rounds 126 to 135 fired in 18 minutes. Rounds 126 to 144 fired in 40 minutes. Rounds 115 to 144 fired in 1 hour and 7 minutes.	Check tapped gently into seat, and after firing removed by extractor. No escape of gas.
	Gun washed out.	
	Fired in 20 minutes.	

Record of firing with 8-inch Yates breech-loading rifle, at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity.	Recoil.
		1885.		*Lbs.*		*Lbs.*	° ′	*Pounds.*	*Feet.*	*Feet.*
P. M. — Barometer, 29.965; thermometer, 63; humidity, 92.	155	Oct. 2	Du Pont's hexagonal E. V. L. Density, 1.750; granulation, 72.	35	Hotchkiss	181	—30	....	....	4.50
	156	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	157	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	158	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	159	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	160	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	161	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	162	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	163	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	164	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	165	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	166	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	167	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	168	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	169	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	170	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	171	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	172	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	173	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	174	Oct 2		35	Hotchkiss	181	—30	....	....	4.50
	175	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	176	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	177	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	178	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	179	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	180	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	181	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	182	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	183	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	184	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	185	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	186	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	187	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	188	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	189	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50
	190	Oct. 2		35	Hotchkiss	181	—30	....	....	4.50

Hook, N. J., from September 24, 1885, *to March* 26, 1886—Continued.

Wind—strength and direction.			Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
From front and left 87°—24 miles an hour.	Fired into sand butt for endurance.	Gun washed out, examined, and star-gauged.	
		Rounds 155 to 220 fired in 2 hours and 16 minutes.	Check tapped gently into seat, and after firing removed by extractor. No escape of gas.
			Rammer used to eject gas-check. Slight escape of gas along lower element of check.

Record of firing with 8-inch Yates breech-loading rifle, at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity.	Recoil.
		1885.		*Lbs.*		*Lbs.*	'	*Pounds.*	*Feet.*	*Feet.*
P. M. — Barometer, 29.965; thermometer 63; humidity, 92.	191	Oct. 2	Du Pont's hexagonal E. V. L. Density, 1.750; granulation, 72.	35	Hotchkiss ..	181	—30	....	....	4.50
	192	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	193	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	194	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	195	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	196	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	197	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	198	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	199	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	200	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	201	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	202	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	203	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	204	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	205	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	206	Oct. 2		35	Hotchkiss .	181	—30	....	....	4.50
	207	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	208	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	209	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	210	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	211	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	212	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	213	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	214	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	215	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	216	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	217	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	218	Oct. 2		35	Hotchkiss ..	131	—30	....	....	4.50
	219	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
	220	Oct. 2		35	Hotchkiss ..	181	—30	....	....	4.50
P. M. — Barometer, 29.912; thermometer, 84.9; humidity, 100.	221	1886. Jan. 19		35	Hotchkiss ..	180	—35	....	....	3.33

Hook, N. J., from September 24, 1885, to March 26, 1886—Continued.

Wind—strength and direction.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
From front and left 87°—24 miles an hour.	Fired into sand butt for endurance. Rounds 155 to 220 fired in 2 hours and 16 minutes.	Rammer used to eject gas-check. Slight escape of gas along lower element of check.
		Rammer used to eject gas-check. Slight escape of gas along lower element of check.
	Gun washed out, examined, and star-gauged.	During the firing of this gun, after gas-check had been removed, it has been washed on the outside with wet waste and then wiped with oiled waste, and its seat in gun has been wiped out after each round.
From rear and right 43°—14 miles an hour.	Fired into sand butt.	New steel gas-check inserted and removed easily before firing with hook. Stuck after firing, and removed with considerable difficulty by the assistance of pinch bar. Examination showed slight distortion of the gas-check due to eccentricity in the seat.

Record of firing with 8-inch Yates breech-loading rifle, at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity.	Recoil.
		1886.		*Lbs.*		*Lbs.*	°	*Pounds.*	*Feet.*	*Feet.*
P. M. — Barometer, 30.303; thermometer, 30; humidity, 67.	222	Feb. 17	Du Pont's Hexagonal E. V. L. Density, 1.750; granulation, 72.	35	Hotchkiss (rebanded).	180	—35	....	....	.....
	223	Feb. 17		35		180	—35	....	....	3.50
	224	Feb. 17		35		180	—35	....	....	3.58
	225	Feb. 17		35		180	—35	....	....	3.75
	226	Feb. 17		35		180	—35	....	....	3.67
	227	Feb. 17		35		180	—35	....	....	3.92
	228	Feb. 17		35		180	—35	27,700	....	3.92
	229	Feb. 17		35		180	—35	28,750	....	3.92
	230	Feb. 17		35		180	—35	....	....	3.92
	231	Feb. 17		37		180	—35	29,650	....	3.92
	232	Feb. 17		35		181	—40	....	....	3.91
	233	Feb. 17		35		181	—40	....	....	3.92
	234	Feb. 17		35		181	—40	....	....	3.96
	235	Feb. 17		35		181	—40	....	....	3.92
	236	Feb. 17		35		181	—40	....	....	3.92
	237	Feb. 17		35		180	—40	....	....	3.92
	238	Feb. 17		35		180	—40	....	....	3.92
	239	Feb. 17		35		180	—40	....	....	3.92
	240	Feb. 17		35		180	—40	....	....	3.92
	241	Feb. 17		35		180	—40	....	....	3.92
A. M. — Barometer, 30.186; thermometer, 39; humidity, 70.	242	Feb. 18	Du Pont's Hexagonal E. V. K. Density, 1.750; granulation, 72.	35		182	—40	28,700	....	3.96
	243	Feb. 18		35		182	—40	31,652	....	3.96
	244	Feb. 18		35		182	—40	....	....	4.00
	245	Feb. 18		35		182	—40	....	....	4.00
	246	Feb. 18		35		181	—40	....	....	4.00
	247	Feb. 18		35		181	—40	....	....	4.00
	248	Feb. 18		35		181	—40	....	....	4.08
	249	Feb. 18		35		181	—40	....	....	4.08
	250	Feb. 18		35		180	—40	....	....	4.10
	251	Feb. 18		35		180	—40	....	....	4.10
	252	Feb. 18		35		180	—40	....	....	4.12
	253	Feb. 18		35		180	—40	....	....	4.16
	254	Feb. 18		35		180	—40	....	....	4.16
	255	Feb. 18		35		180	—40	....	....	4.16
	256	Feb. 18		35		180	—40	....	....	4.16
	257	Feb. 18		35		180	—40	....	....	4.16

Hook, N. J., from September 24, 1885, to March 26, 1886—Continued.

Wind—strength and direction.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Before round 222 gas-check seat reamed out so as to increase pitch $\frac{1}{16}$ inch on a side. Aluminum bronze gas-check.		
From front and right 43°—8 miles an hour.	Gas marks as in preceding round. Check removed as in rounds 222 and 223 by new extractor without difficulty.	Marks from gas on under side of check.
		Marks of gas all around gas-check, but most marked on under side.
		Gas-check removed with considerable difficulty.
		Gas-check removed with considerable difficulty.
	Fired into sand butt for endurance.	Gas-check removed with considerable difficulty. Pieces of bag on outside with gas marks.
		Gas check removed with less difficulty. Gas marks as before.
		Gas check removed with much difficulty. Gas marks as before.
	Gas-check removed with considerable difficulty. Gas marks as before.	
	After round 241 a defect in bronze gas-check (presenting honey-combed appearance allowed water to percolate.	
From front and right 43°—16 miles an hour.	Before round 242 lip beveled on gas-check.	Marks of gas as before, but less in extent. Check removed easily.
		Marks of gas as before, but less in extent. Check removed easily.
		Marks of gas as before, but less in extent. Removed easily.
	Cartridge in tin case.	Gas-check removed with considerable difficulty. Check marked badly by gases. Body of tin case blown out.
	Gas check removed with more or less difficulty and badly marked by gas.	
	Gas-check badly smeared with parts of bag and other products and removed with more difficulty than in previous rounds with this check.	
	Gun washed out before check was removed.	

Record of firing with 8-inch Yates breech-loading rifles, at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity.	Recoil.
		1886.		*Lbs*		*Lbs.*	° '	*Pounds.*	*Feet.*	*Feet.*
P. M. — Barometer, 30.141; thermometer, 44; humidity, 77.	258	Feb. 18	Du Pont's hexagonal E. V. K. Density, 1.750; granulation, 72.	35	Hotchkiss (rebanded).	180	—40	....	....	4.16
	259	Feb. 18		35		179	—40	....	....	4.16
	260	Feb. 18		35		179	—40	....	....	4.16
	261	Feb. 18		35		179	—40	....	....	4.16
	262	Feb. 18		35		179	—40	....	....	4.16
	263	Feb. 18		35		179	—40	....	....	4.16
	264	Feb. 18		35		179	—40	....	....	4.16
	265	Feb. 18		35		177	—40	....	....	4.16
	266	Feb. 18		35		177	—40	....	....	4.16
	267	Feb. 18		35		177	—40	....	....	4.16
	268	Feb. 18		35		177	—40	....	....	4.16
	269	Feb. 18		35		176	—40	....	....	4.25
	270	Feb. 18		35		176	—40	....	....	4.25
	271	Feb. 18		35		176	—40	....	....	4.25
P. M. — Barometer, 29.959; thermometer, 35; humidity, 75.	272	Mar. 10		35		180	—45	32,400	....	4.00
	273	Mar. 10		35		180	—45	32,100	....	4.00
	274	Mar. 10		35		180	—45	....	....	4.00
	275	Mar. 10		35		180	—45	....	....	4.00
	276	Mar. 10		35		180	—45	....	....	4.00
	277	Mar. 10		35		180	—45	....	....	4.00
	278	Mar. 10		35		180	—45	....	....	4.00
	279	Mar. 10		35		180	—45	....	....	4.00
	280	Mar. 10		35		180	—45	....	....	4.00
	281	Mar. 10		35		180	—45	....	....	4.00
P. M. — Barometer, 29.849; thermometer, 53; humidity, 66.	282	Mar. 25		35		180	—45	....	....	3.92
	283	Mar. 25		35		180	—45	....	....	3.92
	284	Mar. 25		35		180	—45	....	....	3.92
	285	Mar. 25		35		180	—45	....	....	3.92

Hook, N. J., from September 24, 1885, to March 25, 1886—Continued.

Wind—strength and direction.			Special remarks about each fire, such as effect on piece, sound of projectile in flight scattering of fragments, &c.
From rear and right 87°—19 miles an hour.	Fired into sand butt for endurance.	Gun star-gauged. Bearing surface of gas-check always smeared after firing with remnants of bag and powder residue and always difficult to remove.	During firing with this check it has been necessary to wash and scrape the bearing surface after each round, the seat being wiped clean with oily waste.
		A new gas-check of aluminum bronze differing from the other as modified (round 242) only in being a more perfect casting. Gas marks along bottom, but remaining bearing surfaces quite clean.	
		Round 271, gas stains all over bearing surface and check removed with great difficulty. Incipient cracks found over inner surface of check, a fact also noted with the other check, but attributed partially to its being a defective casting.	
		New steel check, consisting of steel ring fastened to steel base by six pins passing through thin steel and copper plates.	
From rear and left 3°—16 miles an hour.			Check removed easily. Gas marks and fragments of bag along lower side.
			Check removed with great difficulty. Gas marks all over check, but most marked on lower side.
		Pieces of sheet tin inserted in rear of upper side of check.	Check removed with little difficulty. Gas marks along upper and lower elements. Check taken apart and gas was found to have entered all joints, though not badly.
			Check removed as before and gas marks as before, though more extensive.
			Check removed with considerable difficulty and very considerable escape of gas all around check, though more marked, as usual, below.
		Zinc or copper sheet metal in bore partially covering joints of check.	Check removed with little difficulty and less traces of gas than heretofore.
			Check removed with difficulty. Traces of gas all around and fragments of bag below.
From front and left 87°—3 m. an hour.		New gas-check. Copper cup pinned to steel base, marked "C," and weighs 26 pounds.	
			Removed by iron hooks with little difficulty. Gas marks all along copper and edges of steel.
			Removed by iron hooks with little difficulty. Gas marks as above. Steel found to be set out and pins loosened.
			Removed as above, but rather more easily. Gas marks over copper ring and at bottom over steel slightly.

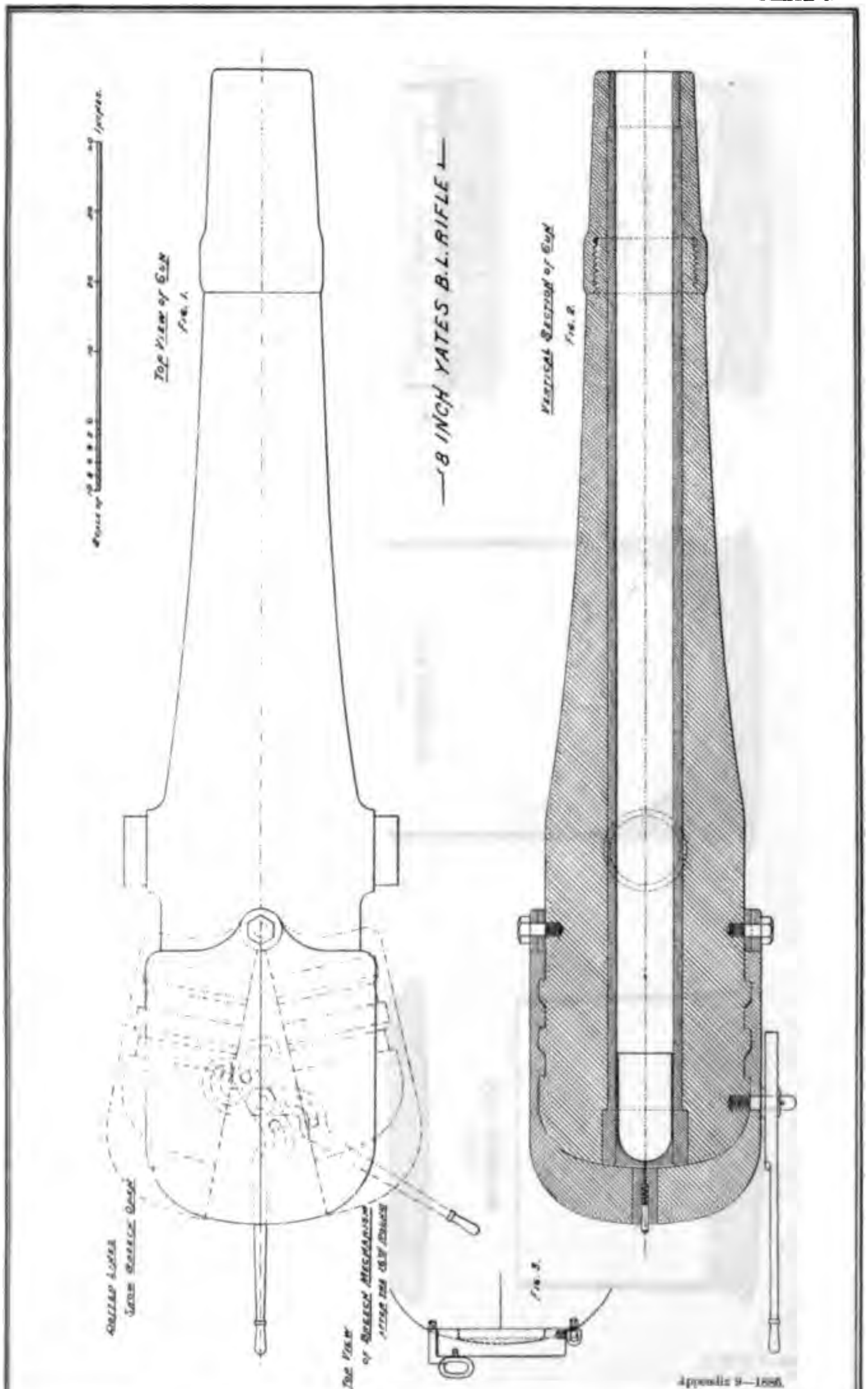
Record of firing with 8-inch breech-loading rifle, at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity.	Recoil.
		1886.		*Lbs.*		*Lbs.*	′	*Pounds.*	*Feet.*	*Feet.*
A. M.—Barometer, 30.044; thermometer, 46.5; humidity, 83.	286	Mar. 26	Du Pont's hexagonal E. V. K. Density, 1.750; granulation, 72.	35	Hotchkiss (rebanded).	180	−50	....	....	3.92
	287	Mar. 26		35		180	−50	....	....	3.92
	288	Mar. 26		35		180	−50	....	....	3.92
	289	Mar. 26		35		180	−50	....	....	3.92
	290	Mar. 26		35		180	−50	....	....	3.92
	291	Mar. 26		35		180	−50	....	....	3.92
	292	Mar. 26		35		180	−50	....	....	3.92
	293	Mar. 26		35		180	−50	....	....	3.92
	294	Mar. 26		35		180	−50	....	....	3.92
	295	Mar. 26		35		180	−50	....	....	3.92
	296	Mar. 26		35		180	−50	....	....	3.92
	297	Mar. 26		35		180	−50	....	....	3.92
	298	Mar. 26		35		180	−50	....	....	3.92
	299	Mar. 26		35		180	−50	....	....	3.92
	300	Mar. 26		35		180	−50	....	....	3.92
	301	Mar. 26		35		180	−50	....	....	3.92
	302	Mar. 26		35		180	−50	....	....	3.92
	303	Mar. 26		35		180	−50	....	....	3.92
	304	Mar. 26		35		180	−50	....	....	3.92
	305	Mar. 26		35		180	−50	....	....	3.02
	306	Mar. 26		35		180	−50	....	....	3.92
	307	Mar. 26		35		180	−50	....	....	3.92
	308	Mar. 26		35		180	−50	....	....	3.92
	309	Mar. 26		35		180	−50	....	....	3.92
	310	Mar. 26		35		180	−50	....	....	3.92
	311	Mar. 26		35		180	−50	....	....	3.92
	312	Mar. 26		35		180	−50	....	....	3.92

Hook, N. J., from September 24, 1885, *to March* 26, 1886—Continued.

Wind—strength and direction.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
From rear and right 87°—16 miles an hour.	Fired into sand butt for endurance. Gas-check marked "R" and weighs 83½ pounds, and is the same as used in rounds 272 to 281, except that steel ring is replaced by copper ring. The hook used to remove the check weighs 13 pounds.	
	Gas-check removed easily by hooks. Copper ring and under side of steel slightly smeared with gas marks, and in rounds 298, 299, 300, 301. 309, 310, and 311, small fragments of bag noticed. Check removed easily by hook. Copper ring smeared with gas marks; also slight marks on under side of steel.	And small fragments of bag at this round.
	Gun burst with great violence into many fragments, demolishing top carriage.	

PLATE I.



8 INCH YATES B.L. RIFLE
Top View of Gun
Fig. 1.
Vertical Section of Gun
Fig. 2.
Fig. 3.

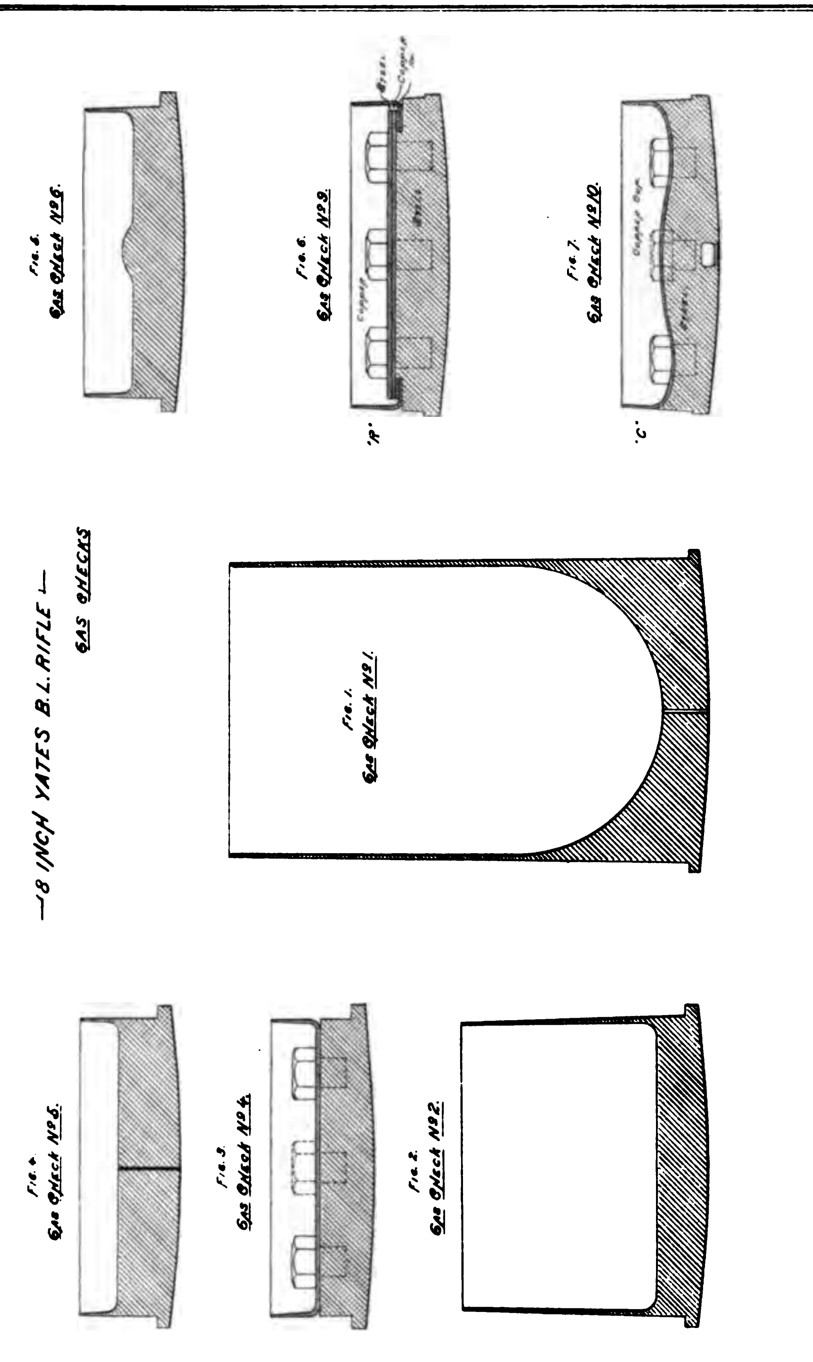
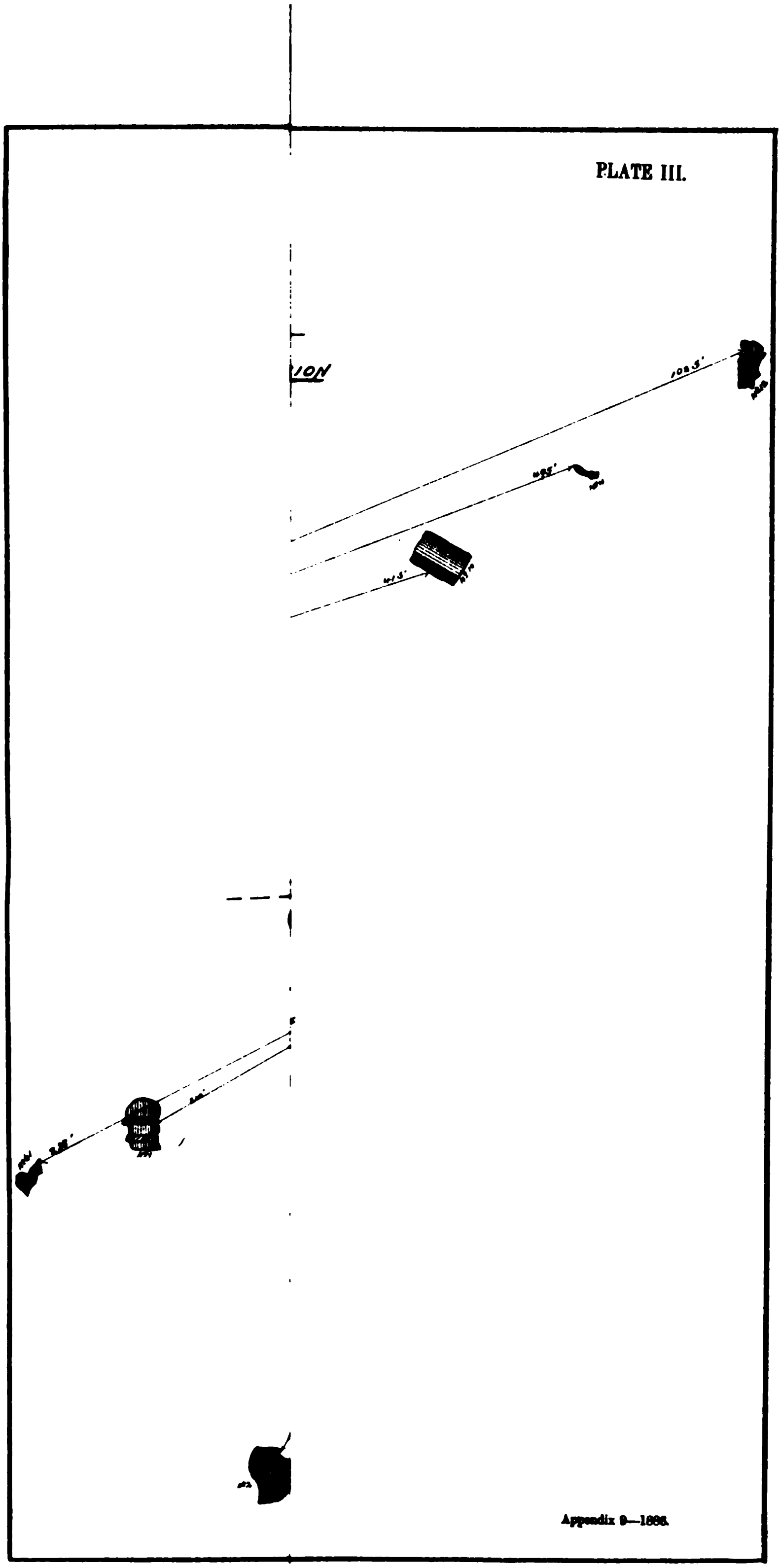
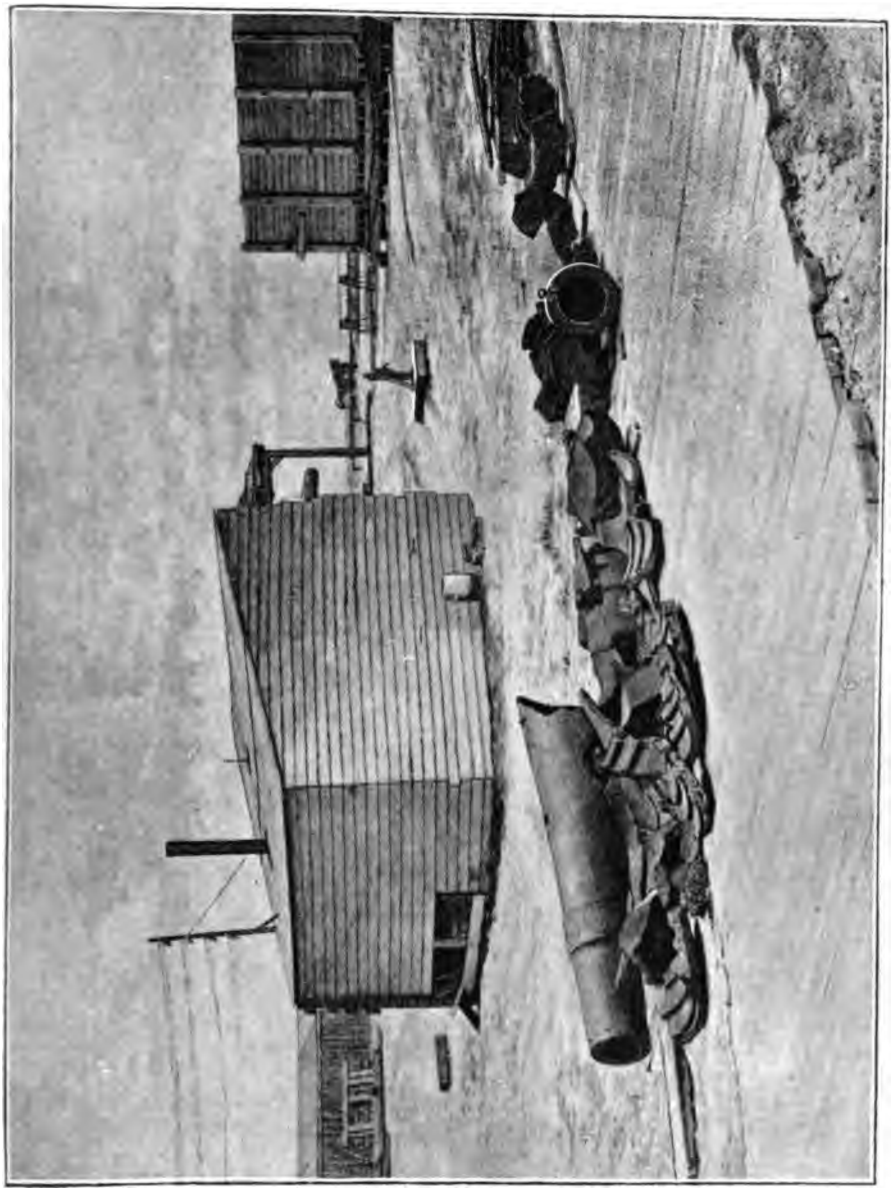

8 INCH YATES B.L. RIFLE
GAS CHECKS
Fig. 5. Gas Check No 6.
Fig. 6. Gas Check No 9.
Fig. 7. Gas Check No 10.
'A'
'C'
Fig. 1. Gas Check No 1.
Fig. 4. Gas Check No 5.
Fig. 3. Gas Check No 4.
Fig. 2. Gas Check No 2.

PLATE III.



Appendix 9—1888.

PLATE V.



8-INCH YATES B. L. GUN.—FRAGMENTS OF EXPLODED GUN.

[Appendix 9—1886.

APPENDIX 10.

PROGRESS REPORT ON THE TWELVE-INCH BREECH-LOADING RIFLE, CAST-IRON, BY THE BOARD APPOINTED UNDER ACT OF JULY 5, 1884.

(1 plate.)

A communication from the Chief of Ordnance to the Ordnance Board, dated September 11, 1885, directed that the 12-inch rifle should be turned over to the "Board for Testing Rifled Cannon, &c.," as soon as a supply of brown prismatic powder for the gun had been obtained. On November 11, 1885, the Ordnance Board, in accordance with the directions above given, turned over the gun to the Testing Board, which had been called upon by its president, Colonel Baylor, to meet at the Ordnance-Proving Ground at Sandy Hook for the purpose of arranging a programme for the test of the gun.

Before the assembling of the Board, in accordance with this call, the gun had been fired 5 proof rounds by the officer in charge of the Proving Ground and 22 rounds by the Ordnance Board. The records of the firing, except for rounds 26 and 27, are published in Appendix No. 20 of the Report of the Chief of Ordnance for 1885. With the exception of the first 5 rounds, which were fired with such charges and projectiles as the contract required should be used to determine the acceptance or rejection of the gun by the United States, the object of the firing up to the 27th round was to test certain powders and projectiles. German cocoa powder and Du Pont's brown prismatic powder of different densities were used, shot weighing 700, 750, and 800 pounds, some with single and some with double bands, were fired, the bands being made either of pure copper or copper alloyed with zinc.

On November 11, 1885, all the members of the "Board for Testing Rifled Cannon, &c.," being present, the gun was received by them.

The gun is described and illustrated in Appendix No. 24 of the Report of the Chief of Ordnance for 1885, the said appendix being the construction report of Capt. D. A. Lyle, who was on foundry duty at the South Boston Iron Works during the fabrication of the piece.

The test of the gun by this Board was taken into consideration, and before arranging a programme for it the following extract from the contract for the powder to be used was read:

* * * One hundred and thirty-five thousand pounds of brown prismatic powder (N. M. type, density 1.853, approximately), at 27 cents per pound.

This powder must fulfill the following conditions when fired from a 12-inch B. L. rifle of 28 caliber length of bore, in charges of 265 pounds, with a projectile of 800 pounds, and a capacity of powder-chamber of 33 cubic inches per pound of powder, or a density of loading of 0.8363, namely: Velocity not less than 1,700 feet at 125 feet from muzzle; pressure not greater than 32,500 pounds per square inch of powder-chamber.

This powder to be delivered in lots of 15,000 pounds, at such times as the United

States may direct, or within five weeks after the receipt of an order from the Chief of Ordnance for each lot of 15,000 pounds—800 pounds of each lot to be delivered for proof-firing prior to its acceptance. * * *

The Board then proceeded to discuss and arrange a programme for the test of the 12-inch cast-iron rifle, with the following result:

A.—*Endurance test.*

The Board decided that 500 rounds, with 265 pounds of powder and 800-pound projectiles, should be fired for this test.

B.—*Test for proof of powder, for kind of band on projectiles, accuracy, ranges at different elevations, and to complete endurance test.*

(1) Three rounds, or as many as may be necessary, from each successive lot of powder, using single-banded projectiles, to prove the powder.

(2) Fifty rounds, to determine best method of banding projectiles—25 rounds with single-banded and 25 rounds with double-banded projectiles—subject to modifications in firing should either method of banding show a decided superiority.

(3) Twenty-five rounds at target, giving greatest practicable range and using the best shot, for accuracy.

(4) Fifty rounds over water, at different elevations, for range.

(5) The remainder of the 500 rounds to be fired as rapidly as convenient to complete the endurance test.

Firing under this programme commenced November 19, 1885, with round No. 28, and the charges used were 265 pounds of Du Pont's brown prismatic powder, except for rounds 34, 35, 36, and 37, when the weights of the charges were, respectively, 100, 150, 200, and 230 pounds of the same powder. The gun had just before the 34th round been mounted upon a pneumatic-gun carriage, and it was necessary to arrive gradually at the maximum charge, in order to test the mechanism of the carriage.

The full firing record of the gun from the first round to the one last fired (the 137th) is appended, although, as before stated, the Testing Board has directed the firing only from the 28th round. A table of enlargements is also inclosed.

The brown prismatic powder was, as stated by the contract, to be furnished in lots of 15,000 pounds, a sample of each lot being first tried before the remainder was delivered. If the sample did not accord with the requirements, then a new sample was to be furnished.

When this Board commenced firing the gun some brown prismatic powder, marked N. R., density 1.814, was on hand, and rounds 28, 29, and 30 were fired with it. The designation of the powder principally furnished was N. V., and up to this time four complete lots of N. V. powder and two samples of the fifth lot have been received. The distinguishing marks of the lots are numbers appended to the letters N. V., as N. V., Lot 1; N. V., Lot 2; N. V., Lot 3. Moreover, the Messrs. Du Pont stated that in each lot there were slight differences, indicated either by the word "sample" or by numerals, as: N. V., Lot 1, sample; N. V., Lot 1. No. 1; N. V., Lot 1, No. 2; N. V., Lot 1, No. 3; N. V., Lot 2, sample; N. V., Lot 2, No. 1; N. V., Lot 2, No. 2, &c.; N. V., Lot 3, sample; N. V., Lot 3, No. 1, &c.

Incidentally connected thus with the test of the gun, lots of brown prismatic powder were tested when the nature of the firing carried on

permitted, but up to the present time a test of the different kinds has not been completed.

The following is a list of the kinds of brown prismatic powder received:

	Density.
N. R	1.814
N. V., Lot 1, sample, No. 1, No. 2, No. 3	1.830
N. V., Lot 2, sample, No. 1, No. 2, No. 3	1.818
N. V., Lot 3, sample, No. 1, No. 2, No. 3	1.826
N. V., Lot 4, sample, No. 1, No. 2, No. 3	1.822
N. V., Lot 5, first sample rejected	1.825

Second sample received.

The kinds which have been tested with the normal charges and the results obtained are indicated in the following:

Table showing muzzle velocities and pressures obtained with 800-pound projectiles and 265-pound charges of brown prismatic powder.

Powder.		Velocity.				Pressure.				Bands.	
Kind.	Density.	Number of rounds.	Maximum.	Minimum.	Mean.	Number of rounds.	Maximum.	Minimum.	Mean.	Number.	Kind.
N. R	1.814	2	1,782	1,765	1,773.5	2	30,700	29,900	30,300	1	Copper.
N. R	1.814	1	1,783	....	....	......	32,100	....	......	2	Do.
N. V., Lot 1.											
Sample	1.830	3	1,760	1,757	1,767.6	3	26,625	24,200	25,042	2	Do.
No. 2	1.830	2	1,734	1,727	1,730.4	4	27,150	25,100	26,394	1	Alloy.
No. 3	1.830	2	1,782	1,778	1,780	4	31,450	28,800	30,106	1	Do.
N. V., Lot 2.											
Sample	1.818	2	1,767	1,743	1,755	6	28,400	27,800	28,075	1	Do.
No. 1	1.818	2	1,692	1,683	1,687.5	4	25,700	24,850	25,238	1	Do.
No. 2	1.818	2	1,712	1,694	1,703	4	26,800	25,300	26,075	1	Do.
No. 3	1.818	2	1,762	1,747	1,754.5	4	30,500	29,850	30,033	1	Copper.
N. V., Lot 3.											
Sample	1.826	3	1,726	1,725	1,725.6	6	27,175	24,400	25,700	1	Alloy.
No. 1	1.826	1	1,712	....	....	2	27,850	27,000	27,425	1	Copper.
No. 2	1.826	2	1,715	1,697	1,706	4	28,000	25,500	26,750	1	Do.
No. 3	1.826	2	1,703	1,701	1,702	4	27,300	26,500	26,900	1	Do.
N. V., Lot 4.											
Sample	1.822	3	1,794	1,792	1,793.6	6	33,000	31,800	32,350	1	Alloy.
N. V., Lot 5.											
Sample*	1.825	2	1,809	1,795	1,802	4	34,400	32,900	33,500	1	Do.

* This sample rejected.

The following kinds of powder received have not as yet been tested with the 800-pound projectile, viz: N. V., Lot 1, No. 1; N. V., Lot 4, Nos. 1, 2, and 3. The sample of N. V., Lot 5, has been rejected, and a new sample lately received has not yet been tested.

Some of the firing was arranged to test the relative merits of single and double bands, of copper or alloy bands, and the effect of changes in the position of the bands, but there have not been sufficient data collected to permit a thorough study of these questions, although there were indications that the cast bands are equal to, perhaps a little superior to, the rolled, and that 3.5 inches from the base of the shot is a slightly better position for the band than 2.5 inches.

The number and nature of the charges fired is given in the following:

Table showing the number of charges of different weights fired.

Powder.		Projectile.			Number of rounds.	Maximum velocity.	Maximum pressure.
			Bands.				
Kind.	Weight.	Weight.	No.	Kind.			
	Lbs.	*Lbs.*					
I. U., hexagonal	150	700	....	Hotchkiss	3	1,878	19,675
I. T., hexagonal	150	700	....	do	2	1,500	*47,250
German cocoa	225	700	2	Copper	1	1,672	25,550
Do	245	700	1	do	1	1,735	28,600
Do	265	700	1	do	1	1,805	30,250
Do	265	750	1	do	3	1,761	32,000
Do	265	750	2	do	2	....	32,500
Do	265	800	1	do	1	1,710	31,400
Du Pont's brown prismatic	100	700	1	Alloy	1	....	....
Do	150	700	1	do	1	....	....
Do	200	700	1	do	1	....	....
Do	225	700	2	Copper	1	1,516	18,250
Do	230	700	1	Alloy	1	....	23,425
Do	245	700	2	Copper	1	1,593	20,425
Do	245	800	1	do	1	1,646	24,100
Do	265	700	1	do	1	1,630	22,250
Do	265	700	1	Alloy	1	....	28,550
Do	265	750	1	Copper	5	1,810	28,825
Do	265	750	1	Alloy	31	....	32,450
Do	265	800	1	Copper	31	1,839	33,975
Do	265	800	2	do	5	1,783	32,100
Do	265	800	1	Alloy	42	1,809	34,400

* This gauge was driven through the wood (see round 5 of firing record) toward the base of the gun, and this pressure is not considered reliable.

The total number of rounds fired with 265-pound charges of power and 700-pound projectiles was 3; with 265-pound charges and 750-pound projectiles, 41; with 265-pound charges and 800-pound projectiles, 79; or 123 rounds with full charges of powder.

Omitting a round fired with 150 pounds of hexagonal powder and a 700-pound Hotchkiss projectile, which, as stated in a note to the foregoing table, was considered abnormal, the highest pressure developed was 34,400 pounds, and with the same omission the pressure, which was fixed by the contract at 32,500 pounds, was exceeded five times, viz, in the 26th, 72d, 74th, 98th, and 99th rounds, when the excess of pressure, as measured by the gauge, which gave the highest record, was 1,475, 200, 500, 600, 1,900 pounds per square inch, respectively. The mean of all the pressures with 265-pound charges and 800 pound projectiles was 27,998 pounds to the square inch, and is the result of 100 observations, some taken with a single pressure gauge and some with two pressure gauges operating simultaneously.

At the 50th round it was observed that the bore of the gun was slightly eroded circumferentially over both lands and grooves, the surface presenting the appearance of a coarse file with teeth arranged in parallel planes normal to the axis of the piece. This rough surface cut down the rests of the star gauge where they were passed through the bore. At the 96th round erosions appeared on the forward slope of the powder chamber, in the shot chamber, and extended in some cases into the rifled part of the bore. Their general direction was parallel to the axis. Impressions taken showed their depth. At the 125th round another set of impressions showed that the erosions had perceptibly increased, and at the 135th round they had increased still more, the extremities of the eroded surfaces presenting the appearance of fine hair-

lines. At the 137th round a final set of impressions was obtained, and, with photographs taken by means of the electric light, are forwarded herewith.

The best marked erosions, three in number, are situated as follows:

One at the top begins about 7′ $7\frac{11}{16}$″ from face of breech; ends about 7′ $2\frac{9}{16}$″ from face of breech.

One at the right begins about 7′ $7\frac{7}{16}$″ from face of breech; ends about 6′ $9\frac{1}{16}$″ from face of breech.

One just to the right of the bottom of the bore begins about 7′ $4\frac{13}{16}$″ from the face of the breech; ends about 7′ $0\frac{7}{16}$″ from face of breech.

The Board understands that large rifled guns using the present powders are subject to similar injury, and that it is deemed necessary to insert a lining after a certain number of rounds have been fired. The Board has not been able to obtain data to show what particular guns have been so affected or after how many rounds such injuries have occurred.

The 12-inch cast-iron gun in its present condition is believed by the Board to be unsafe, and it is thought that its life will be prolonged by the introduction of a steel lining. It does not, however, consider that sufficient information is in its hands to warrant a recommendation that the gun be lined; but in view of the fact that a 12-inch cast-iron gun lined with steel for a part of its length is in process of fabrication and will probably be soon completed, the Board deems it best that further trial of the 12-inch cast-iron gun be suspended till the new 12-inch gun can be tried and the effect of the steel lining be determined.

J. McALLISTER,
Colonel of Ordnance, President of the Board.
A. MORDECAI,
Lieutenant-Colonel of Ordnance.
F. H. PARKER,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.
D. A. LYLE,
Captain of Ordnance.

Record of firing with 12-inch experimental cast-iron breech-loading rifle at

	Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Elevation.	Pressure per square inch of bore. (New Crusher.)	Instrumental velocity, 126′ 7¼″ from muzzle.	Recoil.
		1885.		*Lbs*		*Lbs*	° ′	*Pounds.*	*Feet.*	*Feet.*
A. M.—Barometer, 30.222; thermometer, 66.3; humidity, 57.1.	1	June 19	Du Pont's hexagonal I U. Density, 1.735; granulation, 11.	150	Hotchkiss (new).	700	— 35	19,600	1,370	3.58
P. M.—Barometer, 30.194; thermometer, 77.3; humidity, 50.	2	June 19		150		700	— 44	19,350	1,351	3.79
	3	June 19		150		700	— 44	19,675	1,373	4.00
									126′ 5¼″	
P. M.—Barometer, 30.032; thermometer, 70.4; humidity, 40.	4	June 23	Du Pont's hexagonal I. T. Density, 1.725; granulation, 30.	150		700	— 55	24,600	1,430	4.52
	5	June 23		150		700	— 60	47,250	1,495	4.67
									126′ 6¼″	
A. M.—Barometer, 30.216; thermometer, 74.6; humidity, 48.	6	June 25	German cocoa powder.	225	Double band B.	700	−1 5	25,550 A 20,850 B	1,666	5.42
									174′	
P. M.—Barometer, 30.163; thermometer, 80.1; humidity, 55.	7	June 25		245	Single band A.	700	−1 5	28,600 A 21,550 B	1,727	5.56
	8	June 25		265		700	−1 7	30,250 A 29,725 B	1,796	5.62
									174′ 1″	
	9	June 25		265		750	−1 10	31,975 A 32,000 B	1,753	5.90
	10	June 25		265		800	−1 10	31,400 A 31,400 B	1,703	5.96

Sandy Hook, N. J., from June 19, 1885, to May 25, 1886—Continued.

Wind—strength and direction.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
From front and left, 48°; 10 miles an hour.	....	Fired into sand-butt; 24½ gallons of oil in each cylinder. Density of loading, 0.582. Rear of chamber for length of 12½ inches closed with wood. Gun closed and opened easily; no escape of gas.
		Density of loading, 0.619. Rear of chamber for length of 15 inches closed with wood.
		Density of loading, 0.785. Rear of chamber for length of 25 inches closed with wood.
From rear and right, 87°; 12 miles an hour.	....	Density of loading, 0.785. Rear of chamber for length of 25 inches closed with wood.
		Density of loading, 0.906. Rear of chamber for length of 30 inches closed with wood.
....	....	Two pressure plugs placed in mushroom-head, marked A and B. Block closed easily; opened with little difficulty; no escape of gas.
From front and right, 48°, 4 miles an hour.	....	Fired into sand-butt to try powder.
From front and right, 48°; 8 miles an hour.	....	Block opened easily, but closed with difficulty; no escape of gas. Before firing clasp on rear of obturator stem replaced by screw-nut and asbestos gas-check, lined as well as covered with asbestos cloth. Opened with ease by one man after firing, and similarly closed after loading, but with more difficulty. Considerable quantity of partially-consumed grains of powder.

Record of firing with 12-inch experimental cast-iron breech-loading rifle at

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore. (New Crusher.)	Instrumental velocity, 174′ 1″ from muzzle.	Recoil.
			Kind.	Weight.	Kind.	Weight.				
		1885.		*Lbs*		*Lbs*	° ′	*Pounds.*	*Feet.*	*Feet.*
A. M.—Barometer, 29.876; thermometer, 69.4; humidity, 67.	11	July 3	Du Pont's brown prismatic N. C.	225	Double band B.	700	—1 10	18,200 A 18,250 B	1,508	4.16
	12	July 3	Du Pont's brown prismatic N. C.	245	Double band B.	700	—1 10	20,425 A 20,200 B	1,586	4.50
	13	July 3	Du Pont's brown prismatic N. C.	265	Single band A.	700	—1 10	21,825 A 22,250 B	1,622	4.96
A. M.—Barometer, 30.075; thermometer, 78.3; humidity, 72.	14	July 8	Du Pont's brown prismatic N. C.	265	Double band B.	600	—1 10	23,625 A 23,850 B	1,576	5.42
	15	July 8	German cocoa powder.	265	Double band B.	750	6	32,400 A 32,325 B	....	5.42
	16	July 8	German cocoa powder.	265	Single band A.	750	6	28,200 A 31,700 B	....	5.42
								(Crusher)	174′ 8″	
P. M.—Barometer, 29.947; thermometer, 81.3; humidity, 52.	17	July 15	German cocoa powder.	265	Double band B.	750	6	....	....	5.06
A. M.—Barometer, 30.068; thermometer, 80.1; humidity, 68.8.	18	July 16	German cocoa powder.	265	Single band A.	750	6	....	....	5.06
P. M.—Barometer, 30.039; thermometer, 57.8; humidity, 92.	19	Sept. 10	Du Pont's brown prismatic powder, received September 9, 1885.	245	Single band C (cast metal).	800	—1 10	23,700 A 24,100 B	1,639	5.79
	20	Sept. 10	Du Pont's brown prismatic powder, received September 9, 1885.	265	Single band C (cast metal).	800	—1 10	26,375 A 26,225 B	1,700	6.12

Sandy Hook, N. J., from June 19, 1885, to May 25, 1886—Continued.

Wind—strength and direction.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering fragments, &c.		
From rear and right, 87°; 11 miles an hour.	....	Fired into sand-butt to try powder.	Block opened easily, but closed with difficulty; no escape of gas. Before firing clasp on rear of obturator stem replaced by screw-nut and asbestos gas check, lined as well as covered with asbestos cloth.
From rear and right, 87°; 6 m. an hour.	....		Opened with ease by one man after firing, and similarly closed after loading, but with more difficulty. Considerable quantity of partially-consumed grains of powder.
			Range (yards).
From rear and right, 45°; 6 m. an hour.	Good flight	Fired over water for range. Time of flight, 11¼ seconds	5,329
	Good flight	Fired over water for range. Time of flight, 11¼ seconds	Lost.
From front and right, 45°; 16 miles an hour.	Good flight	Fired over water for range. Time of flight, 11¾ seconds	5,304
From rear and right, 45°; 5 miles an hour.	Good flight	Fired over water for range. Time of flight, 11¾ seconds	5,292
		Before firing this round the unlocking lever lengthened 4 inches; translating lever 3 inches:	
From front and left, 87°; 18 miles an hour.	....	Fired into sand butt. Cartridge in two sections, 13 prisms of black powder at base of each.	A small amount of unconsumed powder picked up.
			A small amount of unconsumed powder picked up. Block unlocked partially at discharge.

Record of firing with 12-inch experimental cast-iron breech-loading rifle at

	Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Elevation.	Pressure per square inch of bore. (Crusher.)	Instrumental velocity, 174′ 8″ from muzzle.	Recoil.
		1885.		Lbs		Lbs	° ′	Pounds.	Feet.	Feet.
									Horizontal: 184′ 11¼″	
P. M.—Barometer, 30.115; thermometer, 72.4; humidity, 80.	21	Sept. 29	Du Pont's brown prismatic N. M. Density, 1.833.	265	Single band C (cast metal).	800	4	27,700 A 27,550 B	1,687	6.21
	22	Sept. 29		265		800	4	25,200 A 27,350 B	1,679	6.25
	23	Sept. 29		265		800	4	25,200 A 27,300 B	1,681	6.25
	24	Sept. 29		265	Single band A.	800	4	25,150 A 25,650 B	1,679	6.33
	25	Sept. 29		265		800	4	25,750 A 25,650 B	1,675	6.33
									181′ 11″	
P. M.—Barometer, 29.857; thermometer, 47.7; humidity, 64.	26	Nov. 3	Du Pont's brown prismatic N. R. Density, 1.814.	265		800	−1 10	33.975 A 33.875 B	1,805	6.08
	27	Nov. 3		265	Single band A (refired).	800	−1 10	22,250 A 31,850 B	1,831	6.08
									177′ 6″	
P. M.—Barometer, 29.616; thermometer, 50.2; humidity, 87.	28	Nov. 19		265	Single band received from W. P. F. November 17, 1885.	800	5	30,700	1,775	6.08
	29	Nov. 19		265		800	5	29,900	1,758	6.06
									181′ 8″	
P. M.—Barometer, 29.841; thermometer, 42.2; humidity, 60.	30	Nov. 20		265	Double band.	800	−1 10	32,100	1,775	To buffers.
									181′ 11″	
P. M.—Barometer, 30.299; thermometer, 38.6; humidity, 57.	31	Nov. 27	Du Pont's brown prismatic N. V. Lot 1, sample. Density, 1.830.	265		800	−1 10	26,625	1,752	Lost
	32	Nov. 27		265		800	−1 10	24,300	1,749	Lost
	33	Nov. 27		265		800	−1 10	24,200	1,748	5.16

Sandy Hook, N. J., from June 19, 1885, *to May* 25, 1886—Continued.

Wind—strength and direction.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.					
		Time of flight.		Ranges.	Deflection.	
		Seconds.		*Yards.*	*Yards.*	
From front and right, 25°; 8 miles an hour.	Good flight	7½	Fired over water for range. A considerable amount of unconsumed powder picked up.	3,641	17.5, right.	The guide of vent-shield bound, making it very difficult to open block after firing. Vent-shield removed before firing.
	Good flight	7¾		3,650	12.5, right.	
	Good flight	7½		3,739	28.2, left.	
	Good flight	8		3,751	51.2, left.	
	Good flight	7⅝		3,702	18.1, left.	
From rear and right, 87°; 36 miles an hour.	....	Gun mounted on old 12-inch carriage. Small amount of unconsumed powder. Fired into sand butt.				
From rear and left, 26°; 31 miles an hour.	Good flight	Fired over water.	Time of flight, 10 seconds	Range (*yards*). 4,719		
	Good flight		Time of flight, 9⅞ seconds	4,716		
From rear and left, 3°; 6 miles an hour.	....	Fired into sand butt. Buffers considerably injured.				
From rear and left, 3°; 16 miles an hour.	....	Before this round, holes in piston-head of cylinder were reduced from ¾ inch to ⅝ inch and spring catch in locking lever replaced by set-screw. Fired into sand butt. Small amount of unconsumed powder.				

Record of firing with 12-inch experimental cast-iron breech-loading rifle at

	Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Elevation.	Pressure per square inch of bore. (Crusher.)	Instrumental velocity, 174′ from muzzle.	Recoil.
		1885.		*Lbs*		*Lbs*	° ′	*Feet.*	*Feet.*	*Feet.*
A. M.—Barometer, 30.093; thermometer, 49.5; humidity, 74.	34	Dec. 23	Du Pont's brown prismatic N. V. Lot 1. No. 1. Density, 1.830.	100	Single cast band.	700	—1	....	....	....
P. M.—Barometer, 29.953; thermometer, 55; humidity, 37.2.	35	Dec. 23		150		700	—1 5	Less than 18,000.	....	....
	36	Dec. 23		200		700	—1 5			
A. M.—Barometer, 30.465; thermometer, 28.4; humidity, 71.	37	1886. Jan. 20		230		700	—1 10	23,100 A 23,425 B	....	6.71
P. M.—Barometer, 30.446; thermometer, 33.1; humidity, 66.	38	Jan. 20		265		700	—1 10	28,550 A 26,950 B	....	6.35
	39	Jan. 20		265		750	—1 10	27,600 A 26,800 B	....	6.79
	40	Jan. 20		265		800	—1 10	28,000 A 27,400 B	....	6.62
	41	Jan. 20		265		800	—1 10	27,950 A 27,625 B	....	6.79
	42	Jan. 20		265		800	—1 10	28,300 A 27,450 B	....	6.85
	43	Jan. 20		265		800	—1 10	29,825 A 28,150 B	....	6.79
A. M.—Barometer, 30.025; thermometer, 38.5; humidity, 88.	44	Jan. 21		265		800	—1 10	28,175 A 28,550 B	....	6.62
	45	Jan. 21	Dupont's brown prismatic N. V. No. 2, sample; density, 1.818. Received December 30, 1885.	265		800	—1 10	28,400 A 27,800 B	1,736	6.75
	46	Jan. 21		265		800	—1 10	28,100 A 27,800 B	1,760	6.33
P. M.—Barometer, 29.937; thermometer, 38.1; humidity, 100.	47	Jan. 21		265		800	—1 10	28,050 A 28,300 B	....	6.67

***Sandy Hook**, N. J., from June* 19, 1885, *to May* 25, 1886—**Continued.**

Wind—strength and direction.	Counter recoil.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
	Ft. In.	
From front and right 48°; 11 miles an hour.		Gun mounted on pneumatic carriage.
	....	
From front and right 48°; 51 miles an hour.		
	....	
From rear and right 87°; 14 miles an hour.	18	Fired into sand butt to try pneumatic carriage.
From rear and right 87°; 5 miles an hour.	To buffers	
	3 71	
	5 21	
	22¾	
	17½	
	24	
From rear and left 48°; 10 miles an hour.	37	
	19½	
	3 37	Fired into sand butt to try powder.
From rear and left 3°; 8 miles an hour.	23½	

Record of firing with 12-inch experimental cast-iron breech-loading rifle at

	Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Elevation.	Pressure per square inch of bore. (Crusher.)	Instrumental velocity, 185' 1" from muzzle.	Recoil.
		1886.		*Lbs*		*Lbs*	° ′	*Pounds.*	*Feet.*	*Feet.*
P. M.—Barometer, 30.195; thermometer, 29.3; humidity, 61.	48	Feb. 2	Du Pont's brown prismatic N. V. Lot 3. Sample. Density, 1.826.	265	Single cast band.	800	5	26,800 A 24,400 B	1,718	6.50
	49	Feb. 2		265		800	5	27,175 A 25,100 B	1,718	6.56
	50	Feb. 2		265		800	5	26,790 A 26,025 B	1,719	6.54
									178' 9"	
A. M.—Barometer, 30.441; thermometer, 35.6; humidity, 90.	51	Feb. 10	Du Pont's brown prismatic N. V. Lot 1. Density 1.830. No. 1	265	Single band.	750	—1 10	28,025 A 26,700 B	1,766	6.46
	52	Feb. 10	No. 1	265		750	—1 10	28,300 A 27,000 B	1,801	6.54
	53	Feb. 10	No. 1	265		750	—1 10	28,825 A 27,400 B	1,800	6.46
P. M.—Barometer, 30.437; thermometer, 37.9; humidity, 76.	54	Feb. 10	No. 1	265		750	—1 10	27,110 A 27,275 B	1,781	6.54
	55	Feb. 10	No. 1	265		750	—1 10	27,500 A 26,850 B	1,788	6.54
Observation February 19, 1886, a. m. — Barometer, 29.958; thermometer, 48; humidity, 89. A. M.	56	Feb. 19	No. 1	265	Rolled band 2¼" from base.	800	3 15	....	....	6.82
A. M.	57	Feb. 19	No. 1	265		800	3 5	....	....	6.67
A. M.	58	Feb. 19	No. 2	265		800	3 5	....	....	6.71
A. M.	61	Feb. 19	No. 2	265		800	3 5	....	....	6.54
P. M.	64	Feb. 19	No. 2	265		800	3 5	....	....	6.39
A. M.	67	Feb. 24	No. 2	265		800	3 5	....	....	6.58

Sandy Hook, N. J., from June 19, 1885, to May 25, 1886—Continued.

Wind—strength and direction.	Time of flight.	Gun mounted on pneumatic gun-carriage.	Range.	Deflection to left.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
	"		*Yards.*	*Yds.*	
From rear and right, 70°; 17 miles an hour.	Lost	Fired over water to try powder.	4,378	63	
	9¼		4,396	55	
	9⅜		4,396	55	

Wind—strength and direction.	Counter recoil.	
	Feet.	
From rear and left, 48°; 9 miles an hour.	2.83	Before this round bore was found to be eroded across both lands and grooves and in such manner as to make star-gauging very difficult.
	2.12	Fired into sand butt.
	2.50	
From rear and left, 46°; 18 miles an hour.	2.42	
	2.42	

Miles per hour.	Wind	Counter recoil.	Distance from center of target in feet. Vertical. Above.	Below.	Horizontal. Right.	Left.	Distance from center of impact in feet. Vertical. Above.	Below.	Horizontal. Right.	Left.	Remarks
15	For rounds 50, 57, 58, 61, 59, 62, 60. From front.	2.50	Fired at 3,000-yard target. Sighting shot. Over target.								
16		2.79	1.00	......	......	7.00	5.90	.....	.....	6.70	Fired at 3,000-yard target. Target made of 1-inch spruce boards. Target 30×40 feet.
16		2.04	.....	1.50	......	1.00	3.40	.....	.....	0.70	
19		2.04	.....	9.00	......	2.00	.....	4.10	....	1.70	
4		2.50	.....	10.00	2.50	......	.....	5.10	2.80	.....	Round 67, lower locking pinion broke.
16		2.58	....	5.00	6.00	.....	.....	0.10	6.30	....	
			1.00	25.50	8.50	10.00	9.30	9.30	9.10	9.10	Mean vertical deviation from center of impact, 3'.72.
			24.50÷5= 4.90		1.50÷5=0.30		18.60÷5= 3.72		18.20÷5= 3.64		Mean horizontal deviation from center of impact, 3'.64. Mean deviation from center of impact, 5'.20.

Record of firing with 12-inch experimental cast-iron breech-loading rifle at

		Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity, 178' 9" from muzzle.	Recoil.
			1886.		*Lbs*		*Lbs*	° '	*Pounds.*	*Feet.*	*Feet.*
Observation February 19, 1886, p. m. — Barometer, 29.694; thermometer, 41; humidity, 100.	A. M.	59	Feb. 19	Dupont's brown prismatic N. V. Lot 1. Density 1.830. No. 2	265	Rolled band 3½" from base.	800	3 5	....	....	6.62
	A. M.	62	Feb. 19	No. 2	265		800	3 5	....	....	6.46
	A. M.	65	Feb. 24	No. 2	265		800	3 5	....	....	6.58
	P. M.	68	Feb. 24	No. 2	265		800	3 5	....	....	6.54
	P. M.	70	Feb. 24	No. 2	265		800	3 5	....	....	6.33
Observation February 24, 1886, a. m. — Barometer, 30.515; thermometer, 27; humidity, 80.	A. M.	60	Feb. 19	No. 2	265	Cast band 3½" from base.	800	3 5	....	....	6.58
	P. M.	63	Feb. 19	No. 2	265		800	3 5	....	....	6.42
Observation February 24, 1886, p. m.—Barometer, 30.418; thermometer, 35; humidity, 92.	A. M.	66	Feb. 24	No. 2	265		800	3 5	....	....	6.58
	P. M.	69	Feb. 24	No. 2	265		800	3 5	....	....	6.67
	A. M.	71	Feb. 24	No. 2	265		800	3 5	28,800 A 27,375 B	....	6.67

Sandy Hook, N. J., from June 19, 1885, *to May* 25, 1886—Continued.

Wind— Miles per hour.	Wind— Direction.	Counter recoil.	Gun mounted on pneumatic gun-carriage. Distance from center of target in feet. Vertical. Above.	Below.	Horizontal. Right.	Left.	Distance from center of impact in feet. Vertical. Above.	Below.	Horizontal. Right.	Left.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
		Feet.										
20	For rounds 63, 64, 69, from left.	2.15	.....	4.02	......	4.00	.....	2.39	.....	7.38	Fired at 3,000-yard target. Target made of 1-inch spruce boards. Target 30×40 feet.	
17		2.25	Over	......	......	......	.....	.....	.....	.....		Elevation is believed to have exceeded 3° 5′.
16	For rounds 65, 66, 67, from rear.	2.58	5.00	......	9.00	......	6.63	.....	5.64	.....		
2		2.25	.....	5.00	5.52	......	.....	3.37	2.12	.....		
4		2.46	.....	2.50	3.00	......	.....	0.87	.....	0.38		
			5.00	11.52	17.52	4.00	6.63	6.63	7.76	7.76		Mean vertical direction from center of impact, 3′.31.
			6.52÷4= 1.63		13.52÷4= 3.38		13.26÷4= 3.31		15.52÷4= 3.88			Mean horizontal deviation from center of impact, 3′.88. Mean deviation from center of impact, 5′.10.
16	For round 68, from rear and left 45°.	2.08	.....	1.50	......	7.50	3.50	.....	.....	8.00		
8		2.16	.....	2.00	......	......	3.00	.....	.....	0.50		
16		2.75	.....	2.50	3.00	......	2.50	....	2.50	.....		
4	For rounds 70, 71, from front and left 45°.	1.58	.....	7.00	3.00	......	.....	2.00	2.50	.....		
12		1.79	.....	12.00	4.00	......	.....	7.00	3.50	.....		
			.....	25.00	10.00	7.50	9.00	9.00	8.50	8.50		Mean vertical deviation from center of impact, 3′.60.
			25.00÷5= 5.00		2.50÷5= 0.50		18.00÷5= 3.60		17.00÷5= 3.40			Mean horizontal deviation from center of impact, 3′.40. Mean deviation from center of impact, 4.′95.

Record of firing with 12-inch experimental cast-iron breech-loading rifle at

	Number of fire.	Time.	Powder. Kind.		Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Elevation.	Pressure per square inch of bore. (Crusher.)	Instrumental velocity, 174′ 1″ from muzzle.	Recoil.
		1886.			*Lbs*		*Lbs*	° ′	*Pounds.*	*Feet.*	*Feet.*
P.M.—Barometer, 29,999; thermometer, 32; humidity, 68.	72	Mar. 5	Du Pont's brown prismatic N. V. Lot 4; sample. Density, 1.822.		265	Cast band.	800	—1 10	32,700 A 32,500 B	1,786	6.92
	73	Mar. 5			265		800	—1 10	31,800 A 31,850 B	1,787	6.75
	74	Mar. 5			265		800	—1 10	33,000 A 32,250 B	1,784	6.75
P.M.—Barometer, 29,821; thermometer, 37.9; humidity, 61.	75	Mar. 9	Du Pont's brown prismatic N. V. Lot 1. Density, 1.830.	No. 3	265		750	—1 10	30,750 A 30,550 B	....	6.33
	76	Mar. 9		No. 3	265		750	—1 10	32,450 A 22,450 B	....	6.67
	77	Mar. 9		No. 3	265		750	—1 10	....	....	6.58
	78	Mar. 9		No. 3	265		750	—1 10	....	....	6.58
	79	Mar. 9		No. 3	265		750	—1 10	....	....	6.58
	80	Mar. 9		No. 3	265		750	—1 10	....	....	6.42
	81	Mar. 9		No. 3	265		750	—1 10	....	....	6.46
	82	Mar. 9		No. 3	265		750	—1 10	....	....	6.42
	83	Mar. 9		No. 3	265		750	—1 10	....	....	6.50
										173′ 6″	
P.M.—Barometer, 30.250; thermometer, 48; humidity, 78.	84	Mar. 17		No. 2	265		800	—1 10	26,850 A 25,100 B	1,727	6.58
	85	Mar. 17		No. 2	265		800	—1 10	27,150 A 26,425 B	1,720	6.58
	86	Mar. 17		No. 3	265		800	—1 10	31,450 A 29,550 B	1,770	6.67
	87	Mar. 17		No. 3	265		800	—1 10	30,625 A 28,800 B	1,774	6.58
A.M.—Barometer, 30.229; thermometer, 44; humidity, 76.	88	Mar. 18	Du Pont's brown prismatic N. V. Lot 2. No. 1.		265		800	3	27,400 A 27,200 B	Slight entrance of gas in B plug	6.58
	89	Mar. 18			265		800	3 1	29,250 A 28,550 B		6.50
	90	Mar. 18			265		800	3 1	....	....	6.33
	91	Mar. 18			265		800	3 2½	....	....	6.42
	92	Mar. 18			265		800	3 2½	....	....	6.33
	93	Mar. 18			265		800	3 2½	....	....	6.21

Sandy Hook, N. J., from June 19, 1885, *to May* 25, 1886—Continued.

Wind—strength and direction.		Counter recoil.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.		
		Feet.			
From rear and left, 3°; 20 miles an hour.		2.08	Fired into sand butt to try powder. Amount of unconsumed powder not unusually large, but several grains recovered only slightly consumed.		The pinion replacing that broken in 67th round also broken.
		2.92			
		3.00			
From rear and right, 87°; 12 miles an hour.		3.92	Fired into sand butt for endurance.		
		2.58			
		2.42			
		2.62			
		2.25			
		2.16			
		2.29			
		2.08			
		2.00			
			Gun star-gauged.		
From front and right, 48°; 7 miles an hour.		3.25	Fired into sand butt to try powder		Breech mechanism works stiffly, especially in closing.
		2.75			
		2.42			
		2.08	Slight entrance of gas in B plug		
From front and left, 43°;	15	2.29	Fired at 3,000-yard target—30 by 40 feet.	In addition to circumferential marks in bore mentioned heretofore, there are spots near muzzle, which seem to be due to erosion.	Struck target 7 feet below and 5 feet to right.
12 miles an hour.	12	2.46			Struck target 7 feet below and 7 feet to right.
	12	1.75			Struck 50 yards short. Ricochet hit on target 14 feet below and 9 feet right.
	8	1.83			Struck target 6 feet below and 8 feet to right.
	4	1.54			Struck target 4 feet 6 inches below and 7 feet to right.
	8	1.71			Struck target 5 feet below and 4 feet to right.

Record of firing with 12-inch experimental cast-iron breech-loading rifle at

	Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Elevation.	Pressure per square inch of bore. (Crusher.)	Instrumental velocity, 173′ 6″ from muzzle.	Recoil.
		1886.		*Lbs*		*Lbs*	° ′	*Pounds.*	*Feet.*	*Feet.*
P.M.—Barometer, 30.111; thermometer, 48; humidity, 58.	94	Mar. 18	Du Pont's brown prismatic N. V. Lot 2. No. 1.	265	Cast band.	800	3 2½	....	....	5.92
	95	Mar. 18		265		800	3 5	....	....	5.92
	96	Mar. 18		265		800	3 5	....	....	5.83
P.M.—Barometer, 29.089; thermometer, 53; humidity, 72.	97	Apr. 29	Du Pont's brown prismatic N. V. Lot No. 2. Density, 1.818.	265		759	−1 10	26,250 A 27,000 B	.... 173′ 5″	6.08
P.M.—Barometer, 29.950; thermometer, 53; humidity, 66.	98	Apr. 30	Du Pont's brown prismatic. Lot 5; sample. Density, 1.825.	265		800	−1 8	33,100 A 32,900 B	1,787	6.83
	99	Apr. 30		265		800	−1 0	34,400 A 33,600 B	1,801	6.83
P.M.—Barometer, 29.920; thermometer, 71; humidity, 55.	100	May 4	Du Pont's brown prismatic N. V. Lot 2. Density, 1.818. No. 1	265		800	−1 6	25,225 A 24,850 B	1,685	6.58
	101	May 4	No. 1	265		800	−1 6	25,700 A 25,075 B	1,676	6.58
	102	May 4	No. 2	265		800	−1 6	26,800 A 26,700 B	1,705	6.50
	103	May 4	No. 2	265		800	−1 6	25,300 A 25,500 B	1,687	6.50
	104	May 4	No. 2	265		750	−1 6	....	....	6.50
	105	May 4	No. 2	265		750	−1 6	....	....	6.67
P.M.—Barometer, 29.760; thermometer, 80; humidity, 38.	106	May 5	No. 2	265		750	−1 6	....	....	6.67
	107	May 5	No. 2	265		750	−1 6	....	....	7.00
	108	May 5	No. 2	265		750	−1 6	....	....	6.92
	109	May 5	No. 2	265		750	−1 6	....	....	6.92
	110	May 5	No. 2	265		750	−1 6	....	....	7.08
	111	May 5	No. 2	265		750	−1 6	....	....	6.83
P.M.—Barometer, 29.920; thermometer, 63; humidity, 65.	112	May 6	No. 3	265	Rolled band.	800	−1 5	30,500 A 29,900 B	1,754	7.04
	113	May 6	No. 3	265		800	−1 5	29,850 A 29,850 B	1,739	7.08

Sandy Hook, N. J., from June 19, 1885, *to May* 25, 1886—Continued.

Wind—strength and direction.	Counter recoil.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.	
	Feet.		
From front and left, 43°; 17 miles an hour.	2.08	Fired at 3,000-yard target—30 by 40 feet..	Struck 50 feet short. Ricochet hit on target 6 feet below and 4 feet right.
20	1.79		Struck target 6 feet below.
20	1.67		Struck 20 feet short. Ricochet hit on target 10 feet below.
From front and left, 87°; 30 miles an hour.	*		
	1.00	Fired into sand butt. After this round it was observed that the steel breech-receiver projected slightly beyond base of gun above, a situation which was reversed below.	
From front and left, 87°; 30 miles an hour.	1.00	Fired into sand butt to try carriage and powder.	Breech-block opened little stiffly.
	0.75		Breech-block opened little stiffly.
From front and right, 48°; 16 miles an hour.	0.75	Fired into sand butt to try powder	Breech-block locked stiffly, but opened easily.
	0.42		Breech-block locked stiffly, but opened easily.
	0.29		
	0.16		
	0.37		
	0.92		
		Gun star-gauged before firing, and rings about gas-check packing eased.	
From front and right, 48°; 16 miles an hour.	1.50	Fired into sand butt for endurance	Block opened and closed with slight difficulty.
	1.08		
	1.58		
	1.92		
	1.92		
	2.04		
From front and right, 3°; 16 miles an hour.	2.25	Fired into sand butt to try powder. Block opened and closed without difficulty.	
	2.42		

Record of firing with 12-inch experimental cast-iron breech-loading rifle at

	Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Elevation.	Pressure per square inch of bore. (Crusher.)	Instrumental velocity, 173' 5'' from muzzle.	Recoil.
		1886.		*Lbs*		*Lbs*	° '	*Pounds.*	*Feet.*	*Feet.*
P.M.—Barometer, 29.920; thermometer, 63; humidity, 65.	114	May 6	Du Pont's brown prismatic N. V. Lot 3. Density, 1.826. No. 1	265	Rolled band.	800	—1 5	24,900 A 25,750 B	1,682	6.92
									174' 6''	
	115	May 6	No. 1	265		800	—1 5	27,000 A 27,850 B	1,704	6.92
	116	May 6	No. 2	265		800	—1 5	25,500 A 26,700 B	1,698	7.00
	117	May 6	No. 2	265		800	—1 5	26,800 A 28,000 B	1,707	6.92
	118	May 6	No. 3	265		800	—1 5	26,900 A 26,500 B	1,693	6.92
	119	May 6	No. 3	265		800	—1 5	26,900 A 27,300 B	1,695	6.92
P.M.—Barometer, 29.920; thermometer, 59; humidity, 87.	120	May 7	Du Pont's brown prismatic N. V. Lot 4. Density, 1.822. No. 1	265	Rolled band.	800	—1 4	....	....	7.04
	121	May 7	No. 1	265		800	—1 4	....	....	7.04
	122	May 7	No. 2	265		800	—1 4	....	....	7.00
	123	May 7	No. 2	265		800	—1 4	....	....	7.08
	124	May 7	No. 3	265		800	—1 4	....	....	7.08
	125	May 7	No. 3	265		800	—1 4	....	....	7.08
P.M.—Barometer, 29.952; thermometer, 50.5; humidity, 90.	126	May 12	Du Pont's brown prismatic N. V. Lot 2. Density, 1.818. No. 2	265	Cast band.	750	—1 5	....	....	6.75
	127	May 12	No. 2	265		750	—1 5	....	....	6.83
	128	May 12	No. 2	265		750	—1 5	....	....	6.58
	129	May 12	No. 2	265		750	—1 5	....	....	6.75
	130	May 12	No. 2	265		750	—1 5	....	....	6.50
	131	May 12	No. 2	265		750	—1 5	....	....	6.58
	132	May 12	No. 2	265		750	—1 5	....	....	6.58
	133	May 12	No. 2	265		750	—1 5	....	....	6.58
	134	May 12	No. 2	265		750	—1 5	....	....	6.58
	135	May 12	No. 1	265		750	—1 5	....	....	6.50
P.M.—Barometer, 29.620; thermometer, 60; humidity, 72.	136	May 25	Lot 2. Density, 1.818. No. 3	265		750	—1 5	28,600 A 27,600 B	....	6.58
	137	May 25	No. 3	265		750	—1 5	28,300 A 27,800 B	....	6.67

Sandy Hook, N. J., from June 19, 1885, *to May* 25, 1886—Continued.

Wind—strength and direction.	Counter recoil.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
	Feet.	
From front and right, 3°; 16 miles an hour.	2.25	Fired into sand butt to try powder. Block opened and closed without difficulty.
	2.50	
	2.00	
	2.42	
	2.00	
	2.08	
		It was found that pinion was upset.
From front and left, 87°; 12 miles an hour.	2.87	Breech closed easily, but opened with some difficulty.
	2.75	Breech opened with some difficulty, though pinion had been previously eased.
	2.00	
		Fired into sand butt for endurance.
	2.92	Breech opened stiffly; due, however, to gearing.
	3.00	
	3.16	
		Gun star-gauged and impressions taken.
From front and left, 43°; 16 miles an hour.	2.16	Brass pinion for locking eased before firing. Breech opened and closed with comparative ease by two men.
	2.08	Breech opened and closed with more difficulty from upsetting of brass pinion.
	2.08	Fired into sand butt for endurance .... Breech opened and closed with considerable difficulty.
	2.16	
	2.33	
	2.75	
	2.16	
	2.16	
	2.33	
	2.50	
From rear and right, 87°; 32 miles an hour.	2.71	Fired into sand butt. Fired in presence of Naval Board.
	2.08	

Table showing enlargements of bore and chamber of 12-inch experimental cast-iron breech-loading rifle.

Inches from muzzle.	Original diameter of bore.	Enlargement of bore after—							
		5 rounds.	10 rounds.	25 rounds.	33 rounds.	47 rounds.	83 rounds.	105 rounds.	125 rounds.
	Inches.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
268	12.002	—0.001	0.005	0.024	0.031	0.032	0.072	0.084	0.117
267	12.001	— .001	.005	.023	.024	.026	.055	.060	.091
266	12.000	.000	.005	.021	.023	.027	.045	.056	.079
265	12.000	.000	.005	.020	.019	.023	.039	.049	.072
264	12.000	.000	.004	.019	.019	.020	.033	.044	.064
263	12.000	.000	.004	.017	.015	.018	.028	.042	.057
262	12.000	.000	.004	.016	.014	.016	.026	.040	.053
261	12.000	.000	.004	.015	.014	.014	.026	.035	.054
260	12.000	.000	.004	.015	.013	.014	.025	.032	.046
259	12.000	.000	.004	.015	.013	.013	.024	.032	.044
258	12.000	.000	.004	.015	.012	.012	.024	.031	.043
257	12.000	.000	.004	.013	.012	.012	.024	.030	.042
256	12.000	.000	.004	.013	.012	.012	.023	.030	.039
255	12.000	.000	.004	.013	.012	.012	.023	.030	.038
254	12.000	.000	.004	.013	.012	.011	.021	.030	.039
253	12.000	.000	.004	.013	.012	.011	.020	.028	.037
252	12.000	.000	.004	.013	.012	.011	.019	.029	.037
251	12.000	.000	.004	.011	.012	.011	.019	.027	.035
250	12.000	.000	.004	.011	.011	.011	.018	.027	.036
249	12.000	.000	.004	.010	.011	.010	.018	.026	.035
248	12.000	.000	.004	.009	.011	.010	.018	.026	.036
247	12.000	.000	.004	.009	.011	.010	.018	.026	.034
246	12.000	.000	.004	.009	.011	.010	.018	.026	.034
245	12.001	— .001	.003	.008	.000	.009	.017	.026	.033
244	12.001	.000	.003	.008	.009	.009	.016	.024	.033
243	12.001	.000	.003	.009	.008	.008	.016	.025	.034
242	12.001	.000	.002	.008	.008	.008	.016	.024	.033
241	12.001	.000	.002	.007	.008	.008	.016	.024	.033
240	12.001	.000	.002	.007	.008	.007	.015	.025	.032
239	12.001	.000	.002	.006	.007	.007	.014	.024	.032
238	12.001	.000	.002	.003	.007	.007	.013	.021	.032
237	12.000	.001	.003	.005	.007	.007	.014	.023	.033
236	12.000	.001	.003	.005	.007	.007	.013	.024	.032
285	12.000	.001	.003	.005	.007	.007	.013	.024	.032
234	12.000	.001	.003	.005	.006	.007	.013	.024	.031
233	12.000	.001	.003	.005	.006	.007	.012	.022	.031
232	12.000	.001	.003	.004	.006	.006	.012	.021	.031
231	12.000	.001	.003	.004	.006	.006	.012	.021	.028
230	12.000	.001	.003	.004	.006	.006	.012	.021	.027
220	12.000	.001	.003	.005	.006	.006	.012	.020	.026
228	12.000	.001	.003	.004	.006	.006	.011	.019	.025
227	12.000	.002	.003	.004	.006	.006	.011	.018	.025
226	12.000	.002	.008	.004	.007	.006	.011	.017	.023
225	12.001	.001	.002	.003	.006	.006	.010	.015	.023
224	12.001	.000	.002	.004	.006	.006	.009	.015	.023
223	12.002	— .001	.002	.003	.005	.005	.008	.014	.021
222	12.002	— .001	.002	.003	.006	.004	.008	.013	.020
221	12.002	— .001	.002	.003	.006	.004	.008	.014	.019
220	12.002	— .001	.002	.002	.005	.004	.008	.014	.019
219	12.002	.000	.002	.002	.006	.004	.007	....	.018
218	12.002	.001	.002	.002	.006	.004	.007	....	.018
217	12.002	.001	.002	.002	.006	.004	.007	....	.018
216	12.002	.001	.002	.003	.006	.004	.007	....	.018
215	12.002	.001	.002	.003	.006	.004	.007	.013	.018
214	12.002	.001	.002	.002	.005	.004	.007	....	.018
213	12.002	.001	.002	.002	.005	.004	.006	....	.017
212	12.002	.001	.002	.002	.005	.004	.006	....	.016
211	12.002	.000	.002	.002	.005	.003	.006	....	.017
210	12.003	— .001	.001	.001	.004	.002	.004	.011	.016
209	12.003	— .001	.001	.001	.004	.002	.004	....	.016
208	12.003	— .001	.001	.001	.003	.002	.004	....	.016
207	12.002	.000	.002	.002	.003	.003	.005	....	.017
206	12.003	— .001	.001	.001	.003	.002	.004	....	.014
205	12.003	— .001	.001	.001	.003	.002	.004	.012	.014
204	12.003	.000	.001	.000	.003	.003	.004	....	.014
203	12.003	.000	.001	.000	.003	.003	.004	....	.015
202	12.003	.000	.001	.000	.003	.003	.003	....	.014
201	12.003	.000	.001	.001	.003	.003	.003	....	.012
200	12.003	.001	.001	.001	.002	.003	.003	.010	.011
199	12.003	.001	.001	.001	.002	.003	.003	....	.011
198	12.003	.001	.000	.001	.002	.003	.003	....	.011
197	12.003	.001	.000	.001	.002	.002	.003	....	.009
196	12.003	.001	.000	.001	.002	.002	.003	....	.009
195	12.003	.001	.000	.001	.002	.002	.003	.008	.010
194	12.004	— .002	— .001	.000	.001	.001	.002	....	.007
193	12.004	— .002	— .001	.000	.001	.001	.002	....	.007
.92	12.004	— .002	— .001	.000	.001	.001	.002	....	.007

Table showing enlargements of bore and chamber of 12-inch experimental cast-iron breech-loading rifle—Continued.

Inches from muzzle.	Original diameter of bore.	Enlargement of bore after— 5 rounds.	10 rounds.	25 rounds.	33 rounds.	47 rounds.	83 rounds.	105 rounds.	125 rounds.
	Inches.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
191	12.003	—0.001	—0.001	0.001	0.002	0.002	0.002	....	0.008
190	12.003	— .002	— .001	.001	.002	.002	.002	.005	.007
189	12.003	— .001	— .001	.001	.002	.002	.002	....	.007
188	12.003	— .002	— .001	.001	.002	.002	.001	....	.007
187	12.003	— .002	— .001	.001	.002	.002	.002	....	.005
186	12.003	— .002	— .001	.001	.002	.002	.002	....	.005
185	12.003	— .002	— .001	.001	.002	.002	.001	.002	.005
184	12.003	— .002	— .001	.001	.002	.001	.001	....	.004
183	12.003	— .002	— .001	.001	.002	.001	.001	....	.004
182	12.003	— .002	.000	.001	.002	.001	.001	....	.004
181	12.003	— .002	.000	.001	.002	.001	.001	....	.004
180	12.004	— .001	.000	.000	.001	.000	.000	.001	.003
179	12.004	— .001	.000	.000	.001	.000	.001	....	.003
178	12.004	— .001	.000	.000	.001	.000	.001	....	.003
177	12.004	— .001	.000	— .001	.001	.000	.001	....	.003
176	12.004	— .001	.000	— .001	.001	.000	.001	....	.003
175	12.004	— .001	.000	.000	.001	.001	.001	....	.003
174	12.004	— .001	.000	.000	.001	.001	.001	....	.003
173	12.004	— .001	.000	.000	.001	.001	.001	....	.003
172	12.004	— .001	.000	.000	.001	.001	.001	....	.003
171	12.004	— .001	.000	.000	.001	.001	.001	....	.003
170	12.004	— .001	.000	.000	.001	.000	.001	.000	.002
165	12.004	— .001	.000	— .001	.000	.000	.001	....	.001
160	12.003	— .001	.000	.000	.002	.000	.002	.002	.002
155	12.003	— .001	.000	.000	.002	.000	.001	....	.002
150	12.004	— .001	.000	— .001	.001	.000	.000	.001	.001
145	12.004	— .001	.000	— .001	.001	.000	.000	....	.001
140	12.004	— .001	.000	— .001	.001	.000	.000	.000	.001
135	12.004	— .001	— .001	— .001	.001	— .001	— .001	....	.001
130	12.003	.000	.000	.000	.002	.000	.000	.001	.002
125	12.003	— .001	.000	.000	.002	.000	.000	....	.002
120	12.003	— .001	.001	.000	.002	.001	.000	.001	.001
115	12.003	— .002	.000	.000	.002	.000	.000	....	.001
110	12.003	— .002	.000	.000	.001	.000	.000	.001	.001
105	12.003	— .002	.000	.000	.001	.000	.000	....	.001
100	12.003	— .002	.000	.000	.001	.000	.000	.001	.001
95	12.003	— .002	.000	.000	.001	.000	.000	....	.001
90	12.003	— .002	.000	.000	.001	.000	.001	.001	.002
85	12.003	— .001	.000	.003	.004	.002	.006	....	.002
84	12.003	.000	.001	.005	.006	.004	.006	....	.002
83	12.004	.000	.001	.005	.005	.004	.006	....	.002
82	12.005	— .001	.000	.004	.005	.003	.006	....	.000
81	12.005	.000	.002	.005	.005	.004	.006	....	.000
80	12.006	.001	.003	.004	.004	.004	.005	.007	— .001
79	12.008	.000	.003	.004	.002	.002	.003	....	— .002
78	12.009	.000	.002	.004	.000	.002	.003	....	— .002
77	12.009	.000	.002	.005	— .002	.002	.001	....	— .002
76	12.011	— .001	.001	.002	— .005	.001	— .001	....	— .003
75	12.011	— .001	.001	.001	— .005	.001	— .001	....	— .004
74	12.010	— .001	.002	.003	— .004	.001	— .001	....	— .001
73	12.011	.000	.001	.001	— .005	.001	— .002	....	— .001
72	12.011	— .001	.000	.001	— .005	.002	— .002	....	— .002
71	12.010	.000	.001	.002	— .004	.002	— .001	....	— .001
70	12.011	— .002	.000	.001	— .005	.000	— .002	.002	— .002
69	12.009	— .001	.001	.003	— .003	.002	.000	....	— .002
68	12.008	— .001	.001	.001	— .001	.001	.001	....	— .001
67	12.007	— .001	.000	.002	— .001	.001	.002	....	.000
66	12.005	— .001	.001	.001	.001	.002	.002	....	.001
65	12.003	.000	.001	.002	.003	.004	.003	....	.003
60	12.005	— .001	.000	.000	.000	.000	.000	.000	.000
55	12.005	— .002	.000	— .001	.000	.000	.000	....	.000
50	12.003	— .001	.001	— .001	.001	.000	.002	.001	.001
45	12.004	— .002	— .001	— .002	.000	.000	.001	....	.000
40	12.003	.000	.000	— .001	.001	.001	.001	.001	.001
35	12.003	.000	.000	— .001	.002	.000	.001	....	.001
30	12.003	.000	.000	— .001	.001	.000	.001	.001	.001
25	12.003	.000	.000	— .001	.001	.000	.001	....	.001
20	12.003	.000	.000	— .001	.001	.000	.001	.000	.000
15	12.003	.000	.000	— .001	.001	.000	.001	....	.001
10	12.003	.000	.000	— .001	.001	.000	.001	.001	.001
5	12.004	— .001	— .001	— .001	.000	.001	— .001	....	.001
1	12.004	— .001	.000	— .001	.000	.001	— .001	— .001	.001

NOTE.—It was found necessary to change the lands heretofore used in star-gauging this gun, which explains the anomalous results shown at 85 to 65 inches from muzzle. Star-gauging this part of the bore over the original lands showed a uniform enlargement of from 0.001 to 0.004 inch since the 105-inch round.

PLATE I.

BORE OF 12-INCH B. L. RIFLE

AFTER THE 137th ROUND.

TOP OF BORE.

BOTTOM OF BORE.

LEFT OF BORE.

RIGHT OF BORE.

Appendix 10—1886.

MOSS ENG. CO., N. Y.

APPENDIX 11.

PROGRESS REPORT ON THE 12-INCH MUZZLE-LOADING RIFLED MORTAR, CAST-IRON, HOOPED WITH STEEL, BY THE BOARD FOR TESTING RIFLED CANNON, ETC., APPOINTED UNDER THE ACT OF CONGRESS APPROVED JULY 5, 1884.

(1 plate.)

The 12-inch muzzle-loading rifled mortar, cast-iron, hooped with steel, was turned over for trial to the Board for Testing Rifled Cannon, &c., by the Ordnance Board, on July 9, 1885.

After fabrication this mortar was first placed in the hands of the Ordnance Board for preliminary firing, with a view (1) to determine a suitable powder to use; (2) to ascertain the dimensions of the sabots; (3) to see if the walls of the shells had sufficient thickness; and (4) to test the general working of the carriage.

The Ordnance Board fired 44 rounds before the transfer, and the results are contained in its report, forming Appendix 19, Report of the Chief of Ordnance for 1885, page 123, *et seq.*

The details concerning the piece will be found in the Construction Report of the Inspector of Ordnance, U. S. A., Boston, Mass. (See Appendix 25, page 175, *et seq.*, Report of Chief of Ordnance, U. S. A., for 1885.)

The trials of this mortar have progressed as rapidly as circumstances would permit, but are not yet completed.

Principal dimensions.

Total length	inches..	127
Length of rifled portion of bore	do....	92
Length of chamber	do....	19.25
Total length of bore	do....	111.25
Diameter of bore	do....	11.998
Diameter of chamber	do....	11.848
Thickness of metal at breech	do....	16.2
Volume of chamber	cubic inches..	1,819.6
Volume of bore in front of chamber	do....	10,461.5
Total volume of bore	do....	12,281.1
Diameter of cast-iron body under hooping	inches..	*31.03
Exterior diameter of Row A (under row), except A_1	do....	†35.93
Length of Row A	do....	65.75
Exterior diameter of A_1	do....	†37.1
Thickness of Row A (except A_1)	do....	†2.5
Thickness of A_1	do....	†3.01
Number of A hoops	do....	8
Exterior diameter of Row B (outside row), except B_2	do....	†41.50
Length of Row B	do....	54.75
Exterior diameter of B_2 (trunnion hoop)	do....	†41.50

* Diameters of cast-iron body vary for the different zones under the hoops.
† Approximate.

Thickness of Row B (except B_3)	inches..	2.8
Thickness of B_3	do....	3.28
Number of B hoops	do....	6

Weights.

Weight of mortar:	
In pounds	30,330
In American tons (2,000 pounds each)	15.165
In English tons (2,240 pounds each)	13.540+
Preponderance at tangent to breech 124.4 pounds, say pounds	125

RIFLING.

The rifling is polygroove, having an equal number of lands and grooves, and with a twist first increasing and then uniform to the muzzle.

Details.

Grooves:		
Number		40
Width	inch..	0.6425
Depth	do...	0.0595
Width of lands	do...	0.3
Radius of fillet, bottom of lands	do...	0.08
Lands rounded with radius of	do...	0.01

Twist:

Increasing: at origin, 1 turn in 100 calibers; at 3.5 inches from muzzle, 1 turn in 35 calibers.

Uniform: at 3.5 inches from muzzle, 1 turn in 35 calibers; at muzzle, 1 turn in 35 calibers.

Total length of rifled portion of bore	inches..	92
Length of bore having increasing twist	do....	88.5
Length of bore having uniform twist	do....	3.5

VENTING.

The vent (0.2 inch in diameter) has a copper bushing. The projecting portion is hexagonal, to facilitate its removal, when necessary, by means of a wrench. The lower end of the vent-bushing is shaped to the curve of the surface of the chamber.

Position of vent.

Distance from bottom of chamber	inches..	4.95
Distance to left of vertical plane through axis	do....	3.00

PROJECTILES.

These were 12-inch shells filled with enough sand to bring them to a uniform weight of 610 pounds each.

The results given in tables 7 and 8 were obtained with projectiles containing from 22 to 25 pounds of sand.

SABOTS.

Three kinds of Eureka sabots were furnished for the trials, and were marked A, B, and C, in the order of their sensitiveness to expansion, the first named, A, being the least sensivive. These sabots are figured in Plate I, Appendix 19, page 135, Report of Chief of Ordnance for 1885.

It was not deemed advisable to have two sabots, one for use with the full charges and one for use with the half charges of powder.

Experiment showed that sabots A and B were not sensitive enough for use with both charges; they were therefore rejected. Sabot C was found to be better than either of the others, but still not quite sensitive enough. It was modified by turning out more metal from the base and thinning the lip to $\frac{1}{20}$ (″.05) of an inch in thickness. This modified sabot, which will be designated in this report as sabot D, was found to act better than either of the others. Great care was taken to see that this sabot (D) conformed accurately to the templet-gauge. This precaution is necessary if uniformity of action and accuracy of flight are to be secured.

The trials show that these sabots are very sensitive to slight variations in thickness of the lip, and indicate that if the best results are to be obtained, the whole base of the sabot should be machined and carefully gauged.

Sabot D is shown in Plate.

POWDERS.

During the trials, M. W., M. V., E. V. F., hexagonal powders; K. H. C., O. B., O. C., O. B. A. No. 1, O. B. A. No. 2, O. X., O. V., O. V. No. 1, O. V. No. 2, P. G., sphero-hexagonal, and O. U. and O. W. powders were used.

For further information regarding these powders, see below.

VELOCITY AND PRESSURE.

In designing this mortar it was expected that two kinds of powder would have to be used, viz:

For full charges.—Powder of medium quickness; weight of charge, 52 pounds; weight of projectile, 610 pounds; velocity, 975 feet; pressure, 27,000 pounds.

For half-charges.—A quick powder; weight of charge, 26 pounds; weight of projectile, 610 pounds; velocity, 650 to 675 feet; pressure, 11,000 pounds.

For one-third charges.—Velocity, about 520 feet.

Limits of velocity and pressure.

The limits for pressure and velocity were fixed as follows:

For the maximum charge of 52 pounds: Pressure, not to exceed 27,000 pounds per square inch. Velocity, about 975 feet per second.

For the minimum or half-charge of 26 pounds: Pressure, about 11,000 pounds per square inch. Velocity, not less than 650 feet per second.

MEAN PRESSURES AND MEAN VELOCITIES.

(*a*) *With 26-pound charge.*

The following results were obtained with the M. W. and M. V. Du Pont's hexagonal powders.

The results are numbered in order, beginning with the least:

Order.	Powder.	Mean pressure.	Mean velocity.	Sabot.	Remarks.
		Lbs. per sq. inch.	*Feet.*		
1	M. W.	9,500	650.5	A.	
2	M. V. sample	9,625	655	C.	
3	M. V.	10,425	659	C.	25-pound charge.
4	M. V.	12,166	663.3	A.	

(b) *With maximum charges.*

[1. With 48-pound charges and sabot A.]

Order.	Powder.	Mean pressure.	Mean velocity.
		Lbs. per sq. inch.	*Feet.*
1........	M. W. ..	26, 250	957
2........	M. W. ..	30, 750	....

[2. With 52-pound charges and sabot C.]

Order according to pressure.	Powder.	Mean pressure.	Mean velocity.	Order according to velocity.	Remarks.
		Lbs. per sq. inch.	*Feet.*		
1	O. X.	18, 666	958	2	
2	O. C.	19, 725	939. 5	1	
3	P. G.	24, 441	973. 6	3	
4	E. V. F.	25, 000	978	4	
5	K. H. C.	25, 150	992	7	
6	O. B.	25, 250	984. 5	5	
7	O. V.	26, 150	996	8	
8	O. V. No. 1.	26, 300	989	6	Crusher gauge.
9	O. V. No. 1.	26, 833	998. 6	9	
10	O. V. No. 2.	27, 166	1, 002. 3	10	
11	O. V. No. 2.	28, 400	1, 003	11	Crusher gauge.
12	O. B. A. No. 1.	28, 500	1, 014	13	
13	O. W.	31, 500	1, 011	12	
14	O. B. A. No. 2.	31, 500	1, 021	14	

For maximum, minimum, and mean pressures, see table.

POWDERS ADOPTED.

The powders given below were adopted for the maximum and minimum charges to be used in the 12-inch muzzle-loading rifled mortar:

Charge.	Powder.			Density.	Granulation.
	Kind.	Marks.	Weight.		
			Pounds.		
Minimum..........	Du Pont's hexagonal...........	M. V.	26	1. 700	72
Maximum..........	Du Pont's sphero-hexagonal ...	O. V. No. 1.	52	1. 750	100

M. V. powder; charge, 26 pounds.
Mean pressure (5 rounds), 11,020 pounds per square inch.
Instrumental velocity at 90 feet from muzzle = 663.3 feet per second.
Muzzle velocity = 663.90 feet per second.
O. V. No. 1 powder; charge, 52 pounds.
Mean pressure = 26,880 pounds per square inch.
Instrumental velocity at 115 feet from muzzle = 998.6 feet per second.
Muzzle velocity = 1000.63 feet per second.

RECOIL.

The recoil of the top carriage was observed in case of each powder and is noted in the firing record.

TIME OF FLIGHT.

The mean times of flight of the projectiles, weighing 610 pounds, are—

(1) *With M. D. powder; charge, 26 pounds.*

At 28° elevation: From 19.05 seconds to 19.26 seconds.
At 60° elevation: From 35.6 seconds to 35.75 seconds.

(2) *With charges of 52 pounds.*

At 28° elevation: O. B. powder, 27.8 seconds.
O. V. powder, 27.48 seconds.
At 60° elevation: O. B. powder, 50.25 seconds.
O. V. powder, 50.5 seconds.

RANGE AND ACCURACY.

This mortar was fired with the maximum and minimum charges at elevations of 28° and 60°, in order to afford an opportunity for comparison with the Krupp 28^{cm} steel breech-loading mortar. A summary is given below.

For detailed information, see Tables 1 to 10, 15 and 16.

SUMMARY.

Number of series in order of dates when fired.	Piece.	Powder.		Elevation.	Number of rounds.	Mean range.	Probability of striking vessel 330 feet long, 60 feet broad.		Remarks.
		Kind.	Charge.				Vessel normal to plane of fire.	With keel lying in plane of fire.	
			Pounds.	°		Yards.	Per ct.	Per ct.	
1	12-inch M. L. R	M. V.	26	28	5	3,427	35.3	98.75	
3	......do	M. V.	26	28	10	3,331.4	8.75	40.72	1 shot tumbled.
3	......do	M. V.	26	28	9	3,358	12.5	58	Same as above, rejecting 1 shot tumbled.
6	......do	M. V.	26	28	10	3,489.6	38	99	
?	Krupp, 28^{cm}	Black.	19.8	30	?	3,877	34	98.8	
2	12-inch M. L. R	M. V.	26	60	5	3,321	16.5	66.6	
4	......do	M. V.	26	60	9	3,119	1.42	1.31	2 shot tumbled.
4	......do	M. V.	26	60	7	3,234.4	21	49.67	Same as above, rejecting 2 shot tumbled.
9	......do	M. V.	26	60	8	3,259.6	13	44.04	
?	Krupp, 28^{cm}	Black.	19.8	60	?	3,545	24	80.77	
5	12-inch M. L. R	O. B.	52	28	4	6,934.5	13	61.66	
7	......do	O. V.	52	28	10	7,141.8	12.5	41.32	
?	Krupp, 28^{cm}	Black.	39.6	28½	?	7,464	21.2	86.6	
8	12-inch M. L. R	O. V.	52	60	9	6,484.2	0.82	5.01	

EXTREME RANGE.

The extreme ranges at 28° and 60° for the M. V. and O. V. No. 1 powders, were observed as follows:

For M. V. powder; charge, 26 pounds.

Elevation.	Range.	
	Yards.	Miles.
28 degrees	3,476	1.97+
60 degrees	3,366	1.91+

For O. V. No. 1 powder; charge, 52 pounds.

Elevation.	Range.	
	Yards.	Miles.
28 degrees	7,252	4.1
60 degrees	6,992	3.97+

The greatest range observed was 7,388 yards, = 4.2 miles, obtained with 48 pounds of M. W. powder and 28° elevation.

The weight of the shell (610 pounds) was constant throughout the experiments.

ENDURANCE TEST.

The endurance test was fixed at 500 rounds with a shell weighing 610 pounds and using the maximum charge of powder.

The maximum charge of powder was fixed at 52 pounds, but the few rounds fired with 40, 45, 47 pounds and those fired with 48 pounds have been considered as part of this test, since the pressures were near the maximum limit.

The total number of rounds fired from the mortar to date (October 16, 1886) is 381 rounds.

The total number of rounds fired up to October 16, inclusive, for the endurance test, including those mentioned above, is 235 rounds.

The trial for endurance is progressing still as rapidly as circumstances and the nature of the work will permit.

RAPIDITY OF FIRE.

The trials made for rapidity of fire are tabulated below:

Tests for rapidity.

No. of fire.		No. of rounds.	Time required, in minutes.	Average time of firing 1 round, in minutes.	Average number of rounds fired per hour.
From—	To—				
150	167	18	150	8.33	7.2
285	294	10	70	7.0	8.5
332	341	10	79	7.9	7.46
342	351	10	87	8.7	*7

*Nearly.

ENLARGEMENT OF BORE.

The bore of the mortar was star-guaged after the 7th, 12th, 25th, 44th, 63d, 70th, 86th, 109th, 119th, 149th, 170th, 304th, and 381st rounds.

The chamber was star-guaged after the 119th, 149th, 170th, 197th, 304th, and 381st rounds.

A table (Table 17) showing the enlargements of the bore and chamber is appended.

Up to this date the enlargements are insignificant.

ADDENDA.

Table 1.—Results of firing 12-inch M. L. R. mortar with M. V. powder on April 11, 1886.
Table 2.—Results of firing 12-inch M. L. R. mortar with M. V. powder on April 20, 1886.
Table 3.—Results of firing 12-inch M. L. R. mortar with M. V. powder on April 20, 1886, rejecting rounds when shot tumbled.
Table 4.—Results of firing 12-inch M. L. R. mortar with O. B. powder on February 9, 1886.
Table 5.—Results of firing 12-inch M. L. R. mortar with M. V. powder on July 22, 1886.
Table 6.—Results of firing 12-inch M. L. R. mortar with O. V. powder on August 26, 1886.
Table 7.—Results of firing 12-inch M. L. R. mortar with O. V. No. 1 powder on October 7, 1886.
Table 8.—Results of firing 12-inch M. L. R. mortar with M. V. powder on October 8, 1886.
Table 9.—Comparison of 12-inch M. L. R. mortar with Krupp's 28^{cm} steel B. L. R. mortar.
Table 10.—Ballistic data.
Table 11.—Various Du Pont's powders used in the tests.
Table 12.—Velocities and pressures.
Table 13.—Showing maximum, minimum, and mean pressures and velocities.
Table 14.—Firing with different powders and sabots for range, time, and nature of flight.
Table 15.—Firing with sabot *C* for range, time, and nature of flight.
Table 16.—Maximum, minimum, and mean, ranges, deviations, and time of flight, with nature of flight, using different sabots and different powders.
Table 17.—Enlargements of bore and chamber.
Table 18.—Firing record.

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TABLE 1.—*Results of firing 12-inch M. L. mortar with M. V. powder on April* 11, 1885.

[Sabot C.]

Number of round.	Weight of charge.	Elevation.	Range.	Error in range.	Deviation.	Error in deviation.	Nature of flight.
	Lbs.	°	*Yds.*	*Yds.*	*Yds.*	*Yds.*	
110	26	28	3412	−15	74	+0.4	Good.
111	26	28	3463	+36	75	+1.4	Do.
112	26	28	3422	− 5	69	−4.6	Do.
113	26	28	3434	+ 7	76	+2.4	Do.
114	26	28	3404	−23	74	+ 4	Do.
			17135	86	368	9.2	
Mean=⅕			3427	17.2	73.6	1.84	
Dispersion:							
Longitudinal						59	
Lateral						7	
Zones, containing 50 per cent. of hits:							
Length						29.1	
Breadth						3.1	
115	26	60	3385	+64	256	+6	Good.
116	26	60	3252	−69	247	−3	Do.
117	26	60	3303	−18	246	−4	Do.
118	26	60	3313	− 8	244	−6	Do.
119	26	60	3352	+31	256	+6	Do.
			16605	190	1249	25	
Mean=⅕			3321	38	250	5	
Dispersion:							
Longitudinal						133	
Lateral						12	
Zones, containing 50 per cent. of hits:							
Length						64.2	
Breadth						8.45	

[Probability of striking a vessel 330 feet long, 60 feet broad.]

At mean range of— Yards.	Vessel with keel.	
	Normal to plane of fire.	Lying in plane of fire.
	Per cent.	*Per cent.*
3427	35.3	98.75
3321	16.5	66.6

TABLE 2.—*Results of firing* 12-*inch M. L. mortar with M. V. powder on April* 20, 1886.

[Sabot C.]

Number of round.	Weight of charge.	Elevation.	Range.	Error in range.	Deviation.	Error in deviation.	Nature of flight.
	Lbs.	°	*Yds.*	*Yds.*	*Yds.*	*Yds.*	
178	26	28	3264	− 67.4	64	− 3.4	Slightly irregular.
179	26	28	3348	+ 16.6	76	+ 8.6	Good.
180	26	28	3296	− 35.4	69	+ 1.6	Do.
181	26	28	3427	+ 92.6	72	+ 4.6	Do.
182	26	28	3476	+144.6	60	− 7.4	Do.
183	26	28	3318	− 13.4	66	− 1.4	Do.
184	26	28	3328	− 3.4	70	+ 2.6	Do.
185	26	28	3408	+ 76.6	72	+ 4.6	Do.
186	26	28	3360	+ 28.6	69	+ 1.6	Do.
187	26	28	3092	−239.4	56	− 11.4	Tumbled.
			33314	718	674	47.2	
Mean = $\frac{1}{10}$			3331.4	71.8	67.4	4.72	
Dispersion:							
Longitudinal						384	
Lateral						16	
Zones, containing 50 per cent. of hits:							
Length						121 3	
Breadth						7.97	
188	26	60	3236	+107	284	+ 43.7	Good.
189	26	60	3284	+165	304	+ 63.7	Do.
190	26	60	3201	+ 82	284	+ 43.7	Do.
191	26	60	3188	+ 69	296	+ 55.7	Do.
192	26	60	3240	+121	284	+ 43.7	Do.
193	26	60	2972	−147	136	−104.3	Tumbled.
194	26	60	2460	−659	− 37	−277.3	*Tumbled.
195	26	60	3284	+165	304	+ 63.7	Good.
197	26	60	3208	+ 89	308	+ 67.7	Do.
					2200		
					37		
			28073	1604	2163	763.5	
Mean = $\frac{1}{9}$			3119	178	240.3	84.83	
Dispersion:							
Longitudinal						824	
Lateral						345	
Zones, containing 50 per cent. of hits:							
Length						300	
Breadth						143	

* Deviation to left in 194.

[Probability of striking a vessel 330 feet long, 60 feet broad.]

At mean range of— Yards.	Vessel with keel.	
	Normal to plane of fire.	Lying in plane of fire.
	Per cent.	*Per cent.*
3331.4	8.75	40.72
3119	1.42	1.31

TABLE 3.—*Results of firing 12-inch M. L. mortar with M. V. powder on April 20, 1886, rejecting rounds when shot tumbled.*

[Sabot C.]

Number of round.	Weight of charge.	Elevation.	Range.	Error in range.	Deviation.	Error in deviation.	Nature of flight.
	Lbs.	°	*Yards.*	*Yards.*	*Yards.*	*Yards.*	
178.......	26	28	3,264	−94	64	−4.7	Good.
179.......	26	28	3,348	−10	76	+7.3	Do.
180.......	26	28	3,296	−62	69	+ .3	Do.
181.......	26	28	3,424	+66	72	+3.3	Do.
182.......	26	28	3,476	+118	60	−8.7	Do.
183.......	26	28	3,318	−40	66	−2.7	Do.
184.......	26	28	3,328	−30	70	+1.3	Do.
185.......	26	28	3,408	+50	72	+3.3	Do.
186.......	26	28	3,360	+2	69	+ .3	Do.
			30,220	472	618	31.9	
Mean =⅑........			3,358	52.4	68.7	3.54	
Dispersion:							
Longitudinal........						212	
Lateral........						16	
Zones containing 50 per cent. of hits:							
Length........						88.6	
Breadth........						6	
188.......	26	60	3,236	+1.6	284	−10.8	Good.
189.......	26	60	3,284	+49.6	304	+9.2	Do.
190.......	26	60	3,201	−31.4	284	−10.8	Do.
191.......	26	60	3,188	−46.4	296	+1.2	Do.
192.......	26	60	3,240	+5.6	284	−10.8	Do.
195.......	26	60	3,284	+49.6	304	+9.2	Do.
197.......	26	60	3,208	−26.4	308	+13.2	Do.
			22,641	212.6	2,064	65.2	
Mean =⅐........			3,234.4	30.4	294.8	9.3	
Dispersion:							
Longitudinal........						96	
Lateral........						24	
Zones containing 50 per cent. of hits:							
Length........						51.37	
Breadth........						15.7	

[Probability of striking a vessel 330 feet long, 60 feet broad.]

At mean range of— Yards.	Vessel with keel—	
	Normal to plane of fire.	Lying in plane of fire.
	Per cent.	*Per cent.*
3,358	12.5	58
3,234.4	21	49.67

TABLE 4.—*Results of firing 12-inch M. L. mortar with O. B. powder, February 9, 1886.*

[Sabot C.]

Number of round.	Weight of charge.	Elevation.	Range.	Error in range.	Deviation.	Error in deviation.	Nature of flight.
	Lbs.	°	*Yards.*	*Yards.*	*Yards.*	*Yards.*	
150	52	28	6,835	−99.5	26	−1.75	Good.
151	52	28	6,953	+18.5	28	+.25	Do.
152	52	28	6,958	+23.5	29	+1.25	Do.
153	52	28	6,992	+57.5	28	+.25	Do.
			27,738	199	111	3.50	
Mean = ¼			6,934.5	49.75	27.75	.90	
Dispersion:							
Longitudinal						157	
Lateral						3	
Zones containing 50 per cent. of hits:							
Length						84	
Breadth						1.52	

[Probability of striking a vessel 330 feet long, 60 feet broad.]

At mean range of — Yards.	Vessel with keel— Normal to plane of fire.	Vessel with keel— Lying in plane of fire.
	Per cent.	*Per cent.*
6,934.5	13	61.66

TABLE 5.—*Results of firing 12-inch M. L. mortar with M. V. powder, July 22, 1886.*

[Sabot D.]

Number of round.	Weight of charge.	Elevation.	Range.	Error in range.	Deviation.	Error in deviation.	Nature of flight.
	Lbs.	°	*Yards.*	*Yards.*	*Yards.*	*Yards.*	
231	26	28	3,532	+42.4	79.2	+2.8	Fair.
232	26	28	3,471	−18.6	75.8	−0.6	Do.
233	26	28	3,492	+ 2.4	77	+0.6	Do.
234	26	28	3,497	+ 7.4	74.8	−1.6	Do.
235	26	28	3,493	+ 3.4	78.4	+2.0	Slightly irregular.
236	26	28	3,505	+15.4	77.1	+0.7	Do.
237	26	28	3,498	+ 8.4	76.2	−0.2	Fair.
238	26	28	3,472	−17.6	75.5	−0.9	Do.
239	26	28	3,476	−13.6	74.9	−1.5	Do.
240	26	28	3,460	−29.6	74.8	−1.6	Do.
			34,896	158.8	763.7	12.5	
Mean = $\frac{1}{10}$ =			3,489.6	15.9	76.4	1.25	
Dispersion:							
Longitudinal						72	
Lateral						4.4	
Zones containing 50 per cent. of hits:							
Length						26.87	
Breadth						2.11	

TABLE 5.—*Results of firing* 12-*inch M. L. mortar with M. V. powder, &c.*—Continued.

[Probability of striking a vessel 330 feet long, 60 feet broad.]

At mean range of — Yards.	Vessel with keel—	
	Normal to plane of fire.	Lying in plane of fire.
	Per cent.	*Per cent.*
3,489.6	38	99+

TABLE 6.—*Results of firing* 12-*inch M. L. mortar with O. V. powder, August* 26, 1886.

[Sabot D.]

Number of round.	Weight of charge.	Elevation.	Range.	Error in range.	Deviation.	Error in deviation.	Nature of flight.
	Lbs.	°	*Yards.*	*Yards.*	*Yards.*	*Yards.*	
246	52	28	7,001	−140.8	8	−20.7	Fluttering.
247	52	28	7,136	− 5.8	44	+15.3	Fair.
248	52	28	7,190	+ 48.2	35	+ 6.3	Good.
249	52	28	7,204	+ 62.2	20	− 8.7	Slightly fluttering.
250	52	28	7,252	+110.2	31	+ 2.3	Good.
251	52	28	7,146	+ 4.2	24	− 4.7	Do.
252	52	28	7,101	− 40.8	30	+ 1.3	Do.
253	52	28	7,168	+ 26.2	23	− 5.7	Do.
254	52	28	7,148	+ 6.2	32	+ 3.3	Do.
255	52	28	7,072	− 69.8	40	+11.3	Do.
			71,418	514.4	287	79.6	
Mean=$\frac{1}{10}$=			7,141.8	51.44	28.7	7.96	
Dispersion:							
Longitudinal						251	
Lateral						36	
Zones containing 50 per cent. of hits:							
Length						86.94	
Breadth						13.45	

[Probability of striking a vessel 330 feet long, 60 feet broad.]

At mean range of — Yards.	Vessel with keel—	
	Normal to plane of fire.	Lying in plane of fire.
	Per cent.	*Per cent.*
7,141.8	12.5	41.82

Table 7.—*Results of firing 12-inch M. L. mortar with O. V. No. 1 powder, October 7, 1886.*

[Sabot D.]

Number of round.	Weight of charge.	Elevation.	Range.	Error in range.	Deviation, right.	Error in deviation.	Nature of flight.
	Lbs.	°	*Yds.*		*Yds.*		
256	52	60	6,244	−240.2	580	+61	Good.
257	52	60	6,648	+163.8	540	+21	Do.
258	52	60	6,992	+507.8	499	−20	Do.
259	52	60	6,344	−140.2	524	+ 5	Do.
260	52	60	6,476	− 8.2	512	− 7	Do.
261	52	60	6,316	−168.2	538	+19	Do.
262	52	60	6,218	−266.2	481	−38	Do.
263	52	60	6,520	+ 35.8	496	−23	Do.
264	52	60	6,600	+115.8	501	−18	Do.
			58,358	1,646.2	467.1	212	
Mean of 9 rounds=			6,484.2	182.9	519	23.5	
Dispersion:						*Yds.*	
Longitudinal						774	
Lateral						99	
Zones containing 50 per cent. of hits:							
Length						309.1	
Breadth						39.72	

[Probability of striking a vessel 330 feet long, 60 feet broad.]

At mean range of—Yards.	Vessel with keel—Normal to plane of fire.	Vessel with keel—Lying in plane of fire.
	Per cent.	*Per cent.*
6,484.2	0.82	5.01

TABLE 8.—*Results of firing 12-inch M. L. mortar with M. V. powder, October 8, 1886.*

[Sabot D.]

Number of round.	Weight of charge.	Elevation.	Range.	Error in range.	Deviation, right.	Error in deviation.	Nature of flight.
	Lbs.	°	*Yds.*		*Yds.*		
275	26	60	3,366	+106.4	231	− 4.6	Good.
276	26	60	3,329	+ 69.4	248	+12.4	Do.
277	26	60	3,277	+ 17.4	236	+ 0.4	Do.
278	26	60	3,267	+ 7.4	237	+ 1.4	Do.
279	26	60	3,258	− 1.6	241	+ 5.4	Do.
280	26	60	3,217	− 42.6	249	+13.4	Do.
281	26	60	3,208	− 51.6	235	− 0.6	Do.
282	26	60	3,155	−104.6	208	−27.6	Do.
Mean of 8 rounds=			3,259.6	50.1	235.6	8.2	
Dispersion:						*Yds.*	
Longitudinal						=211	
Lateral						= 41	
Zones containing 50 per cent. of hits:							
Length						84.65	
Breadth						13.85	

[Probability of striking a vessel 330 feet long, 60 feet broad.]

At mean range of— Yards.	Vessel with keel— Normal to plane of fire.	Vessel with keel— Lying in plane of fire.
	Per cent.	*Per cent.*
3,259.6	13	44.04

TABLE 9.—*Comparison of 12-inch muzzle-loading rifled mortar with Krupp's 28-centimeter steel breech-loading rifled mortar.*

Date of firing.	Nature of mortar.	Caliber.	Number of rounds.	Powder. Kind.	Powder. Granulation.	Powder. Density.	Powder. Weight.	Velocity.	Weight of shell.	Elevation.	Mean range.	Mean error in range.	Mean deviation to the right.	Mean error in deviation.	Dispersion. Longitudinal.	Dispersion. Lateral.	Zones containing 50 per cent. of hits. Length.	Zones containing 50 per cent. of hits. Breadth.	Probability of striking vessel 330 feet long, 60 feet broad. Vessel normal to plane of fire.	Probability of striking vessel 330 feet long, 60 feet broad. With keel lying in plane of fire.
		Inches.					*Lbs.*	*F. S.*	*Lbs.*	° ′	*Yds.*	*Yds.*	*Yds.*	*Yds.*	*Yds.*	*Yds.*	*Yds.*	*Yds.*	*Per ct.*	*Per ct.*
1885.																				
Apr. 11	Cast iron M. L.	12	5	M. V.	72	1.7	26	675	610	28	3,427	17.2	73.6	1.84	59	7	29.1	3.1	35.3	98.75
Apr. 11		12	5				26	675	610	60	3,321	38	250	5	133	12	64.2	8.45	16.5	66.6
1886.																				
Apr.	Cast iron M. L.*	12	10	M. V.	72	1.7	26	675	610	28	3,331.4	71.8	67.4	4.72	384	16	121.3	7.97	8.75	40.72
	....do.†	12	9				26	675	610	60	3,119	178	240.3	84.83	824	345	300	143	1.42	1.31
Apr.	Cast iron M. L.‡	12	9	M. V.	72	1.7	26	675	610	28	3,558	52.4	68.7	3.54	212	16	88.6	6	12.5	58
Apr.		12	7				26	675	610	60	3,234.4	30.4	294.8	9.3	96	24	51.37	15.7	21	49.67
1879.																				
Mar. 20	Krupp 28cm	11.02	5	Black prismatic			19.8	673	475	30	3,877	18.2	....	1.53	42.7	5.6	30.7	2.62	34	98.8
Mar. 20		11.02	5				19.8	673	475	60	3,545	26.3	....	4.9	98.4	12	44.5	8.3	24	80.77
1886.																				
Feb. 9	Cast iron M. L.	12	4	O. B	123	1.725	52	987	610	28	6,934.5	49.75	27.75	0.9	157	3	84	1.52	13	61.66
1879.																				
Mar. 20	Krupp 28cm	11.02	9	Black prismatic.			39.6	984	475	28 36	7,404	28.8	....	1.7	104	6.5	49.2	2.84	21.2	86.6
1886.																				
July 22	Cast iron M. L.	12	10	M. V.	72	1.7	26	675	610	28	3,489.6	15.9	76.4	1.25	72	4.4	26.87	2.11	38	99
Aug. 26	Cast iron M. L.	12	10	O. V.	100	1.750	52	975	610	28	7,141.8	47.44	28.7	7.96	251	36	80.17	13.45	12.5	41.32
Oct. 7	Cast iron M. L. R.	12	9	O. V No. 1	100	1.750	52	1,000	610	60	6,484.2	182.9	519	23.5	774	90	309.1	39.72	0.82	5.01
Oct. 7	Cast iron M. L. R.	12	8	M. V.	72	1.700	26	664	610	60	3,259.6	50.1	235.6	8.2	211	41	84.65	13.85	13	44.04

* 1 shell tumbled. † 2 shells tumbled. ‡ The same as the two preceding, omitting shell that tumbled.

TABLE 10.—*Ballistic data.*

Observed.									Calculated.		
Angle of fire.	Powder.				Velocity.	Range.	Time of flight.	Number of observations.	Height, trajectory.	Angle of fall.	Velocity remaining.
	Kind.	Granulation.	Density.	Weight of charge.							
28	M. V.	72	1. 7	26	675	3,427	19. 26	5	484. 7	30. 8	578. 5
60	M. V.	72	1. 7	26	675	3, 321	35. 75	5	1, 576	6, 416	587. 5
28	O. B.	123	1. 725	52	987	6, 935	27. 8	4	1, 003	3, 217	799. 1
60	O. B.	123	1. 725	52	987	6, 803	50. 25	5	3, 285	65	840
28	M. V.	72	1. 7	26	675	3, 489. 6	19. 05	10	478. 6	30. 5	592
28	O. V.	100	1. 750	52	975	7, 141. 8	27. 48	10	1, 012	31	837. 5
60	O.V. No. 1	100	1. 750	52	1, 000	6, 484	50. 5	9	3, 197	66. 7	786. 8
60	M. V.	72	1. 700	26	664	3, 260	35. 6	8	1, 535	64. 3	568. 9

TABLE 11.—*Various Du Pont powders used in the trials.*

Kind.		Density.	Granulation.	Pressure.	Velocity.	Remarks.
Form.	Marks.					
Hexagonal........	M. W.	1. 725	72	Too high	Too low	
Do.............	M. V.	1. 700	72	Satisfactory.	Satisfactory.	For 26-pound charge.
Do	F. V. F.	1. 750	72	Low	Variable	
Sphero-hexagonal	K. H. C.	1. 775	123	.. do	High	
Do.............	O. B.	1. 725	123	...do	Low	
Do.............	O. C.	1. 750	123	...do	....do	
Do.............	O. B. A. No. 1	1. 725	123	High	High.........	
Do.............	O. B. A. No. 2	1. 725	123	.....do	....do	
Do	O. V.	1. 725	100	Too high.....	Too high....	
Do.............	O. V.	1. 750	100	Too low......	Too low......	
Do.............	O. W.	1. 725	123	Too high.....	Too high....	
Do.............	O. X.	1. 795	100	Low	Little low....	Probably good powder for 52-pound charge if density were lowered slightly.
Do	O. V. No. 1	1. 750	100	Satisfactory	Satisfactory.	For 52-pound charge.
Do.............	O. V. No. 2	1. 750	100	Too high ..	Too high....	
Do.............	P. G.	1. 775	100	Low	Low	

TABLE 12.—*Velocities and pressures.*

[With Sabot A.]

No. of fire.	Powder.		Recoil.	Pressure.		Instrumental velocity (in feet per second).	Remarks.
	Kind.	Charge.		Gauge.	Pounds per sq. inch.		
48	M. W	48	5.42	Rodman	30,750		Elevation, 28°; range lost; flight good; probably A sabot.
						At 115′ from muz.	
54	M. W	48		do	26,250	957	
49	M. W	26		do	9,000	Lost.	
						At 90′ from muz.	
50	M. W	26		do	10,000	646	
51	M. W	26		do	9,500	655	
Mean					9,500	650.5	
						At 115′ from muz.	
52	M. W	45		Rodman	24,750	928	
53	M. V	47		do	22,500	951	
						At 90′ from muz.	
55	M. V	26	4.67	do	12,500	681	
56	M. V	26	4.58	do	12,500	637	
57	M. V	26	4.58	do	11,500	672	
Mean					12,166	663.3+	
144	M. V	26	1.25	Rodman	8,100	Not taken.	60° elevation; flight good; time, 35⅝ seconds.

[With Sabot C.]

No. of fire.	Kind.	Charge.	Recoil.	Gauge.	Pounds per sq. inch.	Instrumental velocity.	Remarks.
						At 130⅝′ from muz.	
120	E. V. F	52	5.79	Rodman	25,000	970	
121	E. V. F	52	5.79	do	25,000	986	
Mean					25,000	978	
132	K. H. C	52	5.42	Rodman	25,500	1,000	
133	K. H. C	52	5.75	do	24,800	984	
Mean					25,150	992	
145	K. H. C	52	5.50	Rodman	20,250	Not taken.	Range, 6,466 yards; deflection, 614 yards right; good flight.
						At 115⅓′ from muz.	
146	O. B	52	4.50	do	25,250	983	
147	O. B	52	5.25	do	25,250	986	
Mean					25,250	984.5	
148	O. C	52	5.16	Rodman	20,250	943	
149	O. C	52	5.08	do	19,250	936	
Mean					19,725	939.5	
						At 90 7/12′ from muz.	
170	M. V. sample	25		Rodman	8,750	624	
168	M. V. sample	26		do	9,500	640	
169	M. V. sample	26		do	9,750	670	
Mean					9,625	655	
171	M. V	25	1.33	Rodman	10,250	672	
172	M. V	25	1.33	do	10,600	646	
Mean					10,425	659	

TABLE 12.—*Velocities and pressures*—Continued.

[With Sabot C—Continued.]

No. of fire.	Powder.		Recoil.	Pressure.		Instrumental velocity (in feet per second).	Remarks.
	Kind.	Charge.		Gauge.	Pounds per sq. inch.		
						At 115$\frac{7}{12}$' from muz.	
173	O. B. A., No. 1	52	4.50	Rodman	28,500	1,014	
174	O. B. A., No. 2	52	4.16	....do	31,500	1,021	
202	O. W	52	6.16	....do	31,500	1,011	
198	O. V	52	6.16	....do	32,000	1,012	
199	O. V	52	6.16	....do	28,500	1,018	
200	O. V	52	6.16	....do	18,750	979	
201	O. V	52	6.16	....do	25,750	987	
203	O. V	52	6.16	....do	25,750	984	
Mean					26,150	996	
						At 115' from muz.	
206	O. V., No. 1	52	5.33	Rodman No. 2	27,250	1,001	
207	O. V., No. 1	52	5.37	Rodman No. 1	25,000	997	
210	O. V., No. 1	52	5.50	Rodman No. 2	28,250	998	
Mean					26,833+	998.6	
208	O. V., No. 2	52	5.50	Rodman No. 2	28,500	1,003	
209	O. V., No. 2	52	5.50	Rodman No. 1	25,250	1,003	
211	O. V., No. 2	52	5.50	Rodman No. 2	27,750	1,001	
Mean					27,166+	1,002.3	
213	O. V., No. 1	52	5.50	Crusher	26,300	989	
214	O. V., No. 2	52	5.50	...do	28,400	1,003	
204	O. X	52	5.33	Rodman No. 2	19,000	956	
205	O. X	52	5.33	Rodman No. 1	21,250	961	
212	O. X	52	5.50	Rodman No. 2	15,750	957	
Mean					18,666	958	
243	P. G	52	5.67	Crusher	23,700	973	
244	P. G	52	5.67	...do	24,625	974	
245	P. G	52	5.67	...do	25,000	974	
Mean					24,441	973.6	

TABLE 13.—*Table showing maximum, minimum, and mean pressures and velocities.*

[With Sabot A.]

No. of fire.		Powder.		No. of rounds.	Pressure.			Instrumental velocity.			
								At foot from muzzle.	Feet per second.		
From—	To—	Kind.	Charge.		Maximum.	Minimum.	Mean.		Maximum.	Minimum.	Mean.
								′ ″			
......	48	M. W	48	1	30,750	....	30,750	....	....	....	....
......	54	M. W	48	1	26,250	....	26,250	115 0	957	....	957.
49	51	M. W	26	3	10,000	9,000	9,500	90 0	655	646	650.5
......	52	M. W	45	1	24,750	....	24,750	115 0	923	....	923.
......	53	M. W	47	1	22,500	....	22,500	115 0	951	....	951.
55	57	M. V	26	3	12,500	11,500	12,166	90 0	681	637	663.3
......	144	M. V	26	1	8,100	....	8,100	Not taken.			....

[With Sabot C.]

120	121	E. V. F	52	2	25,000	25,000	25,000	139 8	986	970	978.
132	133	K. H. C	52	2	25,500	24,800	25,150	139 8	1,000	984	992.
......	145	K. H. C	52	1	20,250	....	20,250	Not taken.			....
146	147	O. B	52	2	25,250	25,250	25,250	115 6	986	983	984.5
148	149	O. C	52	2	20,250	19,250	19,725	115 6	943	936	939.5
......	170	M. V., sample ...	25	1	8,750	....	8,750	90 7	624	....	624.
168	169	M. V., sample ...	26	2	9,750	9,500	9,625	90 7	670	640	655.
171	172	M. V	25	2	10,600	10,250	10,425	90 7	672	646	659.
......	173	O. B. A., No. 1	52	1	28,500	....	28,500	115 7	1,014	....	1,014.
......	174	O. B. A., No. 2	52	1	31,500	....	31,500	115 7	1,021	....	1,021.
......	202	O. W	52	1	31,000	....	31,000	115 7	1,011	....	1,011.
198	203	O. V	52	5	32,000	18,750	26,150	115 7	1,018	979	996.
206	210	O. V., No. 1	52	3	28,250	25,000	26,883	115 0	1,001	997	998.6
208	211	O. V., No. 2	52	3	28,500	25,250	27,166	115 0	1,003	1,001	1,002.3
......	213	O. V., No. 1	52	1	26,300	(Crusher.)	26,300	115 0	989	....	989.
......	214	O. V., No. 2	52	1	28,400	(Crusher.)	28,400	115 0	1,003	....	1,003.
204	212	O. X	52	3	21,250	15,750	18,666	115 0	961	956	958.
243	245	P. G	52	3	25,000	23,700	24,441	115 0	974	973	973.6

[With Sabot D.]

256	268	O V., No. 1	52	4	27,600	26,200	26,862	Crusher gauge.		....	....
276	278	M. V	26	2	9,500	9,100	9,300	Rodman.		....	....

TABLE 14.—*Firing with different powders and sabots for range, time, and nature of flight.*

[Projectile: Eureka shell, weight 610 pounds.]

No. of fire.	Powder.		Elevation.	Sabot.	Time of flight.	Range.	Deviation.	Nature of flight.
	Kind.	Charge.	°					
45	M. W...	48	28	A	....	7, 388+	....	Good.
46	M. V....	25	60	A	....	3, 362	....	Do.
58	M. W...	26	60	A	Lost.	3, 006	....	First part good; remainder probably irregular.
59	M. W...	26	60	A	31½	2, 663 2, 984. 5	....	Shot tumbled.
60	M. W...	28	60	A	31¼	2, 658	....	Do.
87	M. W...	48	28	A	27¼	6, 663	....	Good.
88	M. W...	48	28	A	27¾	6, 708	....	Do.
89	M. W...	48	28	A	27⅝	Lost.	....	Do.
90	M. W...	48	28	A	27¼	6, 789	....	Do.
91	M. W...	48	28	A	27⅛	6, 766	....	Do.
92	M. W...	48	28	A	27⅛	6, 738	....	Do.
93	M. W...	48	28	A	27⅛	6, 651	....	Do.
94	M. W...	48	28	A	27	6, 679	....	Slightly irregular.
95	M. W...	48	28	A	27⅛	6, 711	....	Good.
96	M. W...	48	28	A	26⅞	6, 679	....	Do.
Mean	....	......	....	....	27. 8	6, 709+		
97	M. V....	26	60	A	31⅞	2, 720	....	Shot tumbled.
98	M. V....	26	60	A	35¼	3, 497	....	Good.
99	M. V....	26	60	A	Lost.	......2, 498	....	Shot tumbled.
Mean	....	......	....	....	33. 5+	2, 905	....	
61	M. W...	26	60	B	33	3, 009	....	Do.
							Right.	
122	E. V. F .	52	28	C	26⅜	6, 502	172	Good.
123	E. V. F .	52	28	C	26⅞	6, 689	164	Do.
124	E. V. F .	52	28	C	27⅜	6, 659	165	Do.
125	E. V. F .	52	28	C	27⅝	6, 653	168	Do.
126	E. V. F .	52	28	C	27⅜	6, 982	174	Do.
Mean	....	......	....	....	27. 2	6, 697	168. 6	
127	E. V. F .	52	60	C	50⅞	6, 643	521	Do.
128	E. V. F .	52	60	C	49⅞	6, 681	501	Do.
129	E. V. F .	52	60	C	49¼	6, 496	489	Do.
130	E. V. F .	52	60	C	49⅞	6, 724	519	Do.
131	E. V. F .	52	60	C	49⅞	6, 614	522	Do.
Mean	....	......	....	....	50. 0	6, 631. 6	510. 4	
134	K. H. C .	52	28	C	27⅜	6, 866	120	Do.
135	K. H. C .	52	28	C	27⅛	6, 813	121	Fluttering.
136	K. H. C .	52	28	C	27¼	6, 726	134	Good.
137	K. H. C .	52	28	C	27⅜	6, 728	136	Do.
138	K. H. C .	52	28	C	Lost.	6, 791	144	Slightly fluttering.
Mean	....	......	....	....	27. 4	6, 784. 8	131	
139	K. H. C .	52	60	C	49⅞	6, 422	413	Fluttering.
140	K. H. C .	52	60	C	50¼	6, 529	442	Slightly fluttering.
141	K. H. C .	52	60	C	50	6, 528	440	Fluttering.
142	K. H. C .	52	60	C	49⅞	6, 508	439	Slightly fluttering.
143	K. H. C .	52	60	C	49¾	6, 585	392	Good.
Mean	....	......	....	....	49. 9+	6, 514. 4	425. 2	
154	O. B	52	60	C	50½	6, 804	392	Do.
155	O. B	52	60	C	50	6, 844	392	Do.
156	O. B	52	60	C	50¼	6, 755	405	Do.
157	O. B	52	60	C	50¼	6, 752	414	Do.
158	O. B	52	60	C	50⅛	6, 862	409	Do.
Mean	....	......	....	....	50. 2+	6, 803. 4	402. 4	

TABLE 14.—*Firing with different powders and sabots, &c.*—Continued.

No. of fire.	Powder. Kind.	Powder. Charge.	Elevation.	Sabot.	Time of flight.	Range.	Deviation.	Nature of flight.
			°					
159	O. C	52	28	C	25¾	6,066	61	Good.
160	O. C	52	28	C	26¼	6,031	44	Do.
161	O. C	52	28	C	26¼	6,068	53	Flight not perfectly smooth.
162	O. C	52	28	C	26¼	6,287	64	Do.
Mean	....	......	......	....	26.1+	6,118	55.5	
163	O. C	52	60	C	47⅞	5,836	384	Good.
164	O. C	52	60	C	47¾	5,883	397	Do.
165	O. C	52	60	C	47¾	6,118	394	Do.
166	O. C	52	60	C	47¾	5,888	389	Do.
167	O. C	52	60	C	47⅞	6,077	407	Slightly fluttering.
Mean	....	......	....	....	47.8	5,960.4	394.2	
228	M. V	26	28	D	....	Fired over water to try sabots of various thickness of lip.		
229	M. V	26	28	lip $\frac{1}{20}$″ thick	....			
230	M. V	26	28	lip $\frac{1}{10}$″ thick	....			
241	M. V	26	60	D	35	Down beach.	....	Fired for Brazilians.
242	M. V	26	60	D	35			
							Right.	
256	O. V	52	60	D	50¾	6,244	580	Good.
257	O. V	52	60	D	50¾	6,648	540	Do.
258	O. V	52	60	D	50¾	6,992	499	Do.
259	O. V ..	52	60	D	50¾	6,344	524	Do.
260	O. V	52	60	D	50	6,476	512	Do.
261	O. V	52	60	D	50	6,316	538	Do.
262	O. V	52	60	D	50½	6,218	481	Do.
263	O. V	52	60	D	50½	6,520	496	Do.
264	O. V	52	60	D	Lost.	6,600	501	Do.
Mean	....	......	....	....	50.5	6,484.2	519	
275	M. V	26	60	D	35½	3,366	231	Do.
276	M. V	26	60	D	Lost.	3,329	248	Do.
277	M. V	26	60	D	35¾	3,277	236	Do.
278	M. V	26	60	D	35½	3,267	237	Do.
279	M. V	26	60	D	35¾	3,258	241	Do.
280	M. V	26	60	D	35½	3,217	249	Do.
281	M. V	26	60	D	36	3,108	235	Do.
282	M. V	26	60	D	35½	3,155	208	Do.
Mean	....	......	....	....	35.6	3,259.6	235.6	

TABLE 15.—*Firing Eureka shell with Sabot C for range, time, and nature of flight.*

[Weight of shell = 610 pounds.]

(1) *With M. W. powder; density*, 1.725; *granulation*, 72.

[Elevation of 28 degrees.]

Number of fire.	Charge of powder.	Recoil.	Time of flight.	Range.	Deflection.	Nature of flight.
	Pounds.	*Feet.*	*Seconds.*	*Yards.*	*Yards.*	
67	48	4.92	24⅞	5,614	....	Good.
68	48	5.16	Lost.	6,802	....	Do.
69	48	5.16	28	6,452	....	Fair.
79	48	4.33	28⅛	7,019	....	Good.
80	48	4.33	28⅜	7,045	....	Do.
81	48	4.42	27	6,607	....	Fluttering.
82	48	4.33	27⅞	6,762	....	Good.
Mean of 7 rounds...	....	4.66+	27.7	6,614.4+	....	

TABLE 15.—*Firing Eureka shell with Sabot C for range, &c.*—Continued.

Number of fire.	Charge of powder.	Recoil.	Time of flight.	Range.	Deflection.	Nature of flight.
	Pounds.	*Feet.*	*Seconds.*	*Yards.*	*Yards.*	
71	26	4.08	20	3,349	....	Good.
72	26	4.00	19½	3,346	....	Slightly fluttering.
73	26	3.92	19⅛	3,340	....	Good.
74	26	4.08	19	3,264	....	Do.
Mean of 4 rounds	....	4.02	19.4	3,325	....	
100	26	4.50	18¾	3,254	76 right.	Do.
101	26	4.50	18¾	3,280	81	Do.
102	26	4.69	19	3,474	52	Do.
103	26	4.67	18¾	3,332	86	Do.
104	26	4.67	18¾	3,345	87	Do.
Mean of 5 rounds	....	4.60	18.8	3,337	76.4	
[Elevation of 60 degrees.]						
62	26	1.50	35	3,194	....	Good.
63	26	1.50	35½	3,278	....	Do.
64	26	1.42	34¼	3,185	....	Do.
65	26	1.42	34¾	3,224	....	Slightly irregular.
66	26	1.42	34½	3,236	....	Good.
75	26	1.42	34	3,265	....	Wavy and irregular.
76	26	1.42	34¾	3,204	....	Slightly irregular.
77	26	1.42	34¼	3,197	....	Fair.
78	26	1.42	34¾	3,286	....	Good.
Mean of 9 rounds	....	1.43+	34.5+	3,229.9	....	
105	26	1.33	35	3,179	214 right.	Very slight flutter.
106	26	1.42	34¾	3,130	287	Good.
107	26	1.33	35½	3,213	284	Do.
108	26	1,33	34¾	3,162	286	Do.
109	26	1.23	34½	3,105	312	Do.
Mean of 5 rounds	....	1.34+	34.9	3,157.8	276.6	
83	48	2.75	49¾	6,711	....	Do.
84	48	2.58	49¼	6,607	....	Do.
85	48	2.58	49¾	6,598	....	Do.
86	48	2.58	49½	6,573	....	Do.
Mean of 4 rounds	....	2.62	49.5+	6,622.2+	....	

(2) *With M. V. powder; density*, 1.700; *granulation*, 72.

[Elevation of 28 degrees.]

Number of fire.	Charge of powder.	Recoil.	Time of flight.	Range.	Deflection.	Nature of flight.
215	26	4.16	....	3,399	73.3 right.	Good.
216	26	4.16	....	3,287	68.1	Fair.
217	26	4.25	....	2,890	25.1	Very irregular.
218	26	4.25	....	3,340	63.3	Fair.
219	26	4.25	....	3,401	72.7	Do.
220	26	4.25	....	2,620	58.4 left.	Shot tumbled.
221	26	4.25	....	Fell in sea..	....	Fluttering.
222	26	4.25	....	Fell in sea..	....	Fair.
223	26	4.25	....	2,620	38.7 left.	Shot tumbled.
224	26	4.25	....	3,354	58.7 right.	Good.
Mean of 8 rounds	....	4.23+	....	3,113.8	33.0+right.	
[Elevation of 60 degrees.]						
175	26	1.33	....	3,054	221 right.	Good.
176	26	1.33	....	2,722	89	Wabbled little.
177	26	1.33	....	3,138	241	Good.
225	26	1.67	....	3,254	234.1	Do.
226	26	1.67	....	Fell in sea..	....	Shot tumbled.
227	26	1.67	....	Fell in sea..	....	Good.
144	26	1.25	35¼	3,207	298	Do.
Mean of 5 rounds	....	1.46	....	3,075	216.6 right.	

TABLE 16.—*Showing maximum, minimum, and mean ranges, deviations and time of flight, with nature of flight, using different sabots and different powders.*

[Weight of shell, 610 pounds.]

Number of fire— From.	Number of fire— To.	Powder. Kind.	Powder. Charge.	Sabot.	Elevation.	Time of flight.	Number of rounds fired.	Number of rounds shot tumbled or irregular flight.	Range. Maximum.	Range. Minimum.	Range. Mean.	Deviation, right. Maximum.	Deviation, right. Minimum.	Deviation, right. Mean.	Remarks.
					°	*Seconds*			*Yards.*	*Yards.*	*Yards.*	*Yards.*	*Yards.*	*Yards.*	
..	45	M. W	48	(? A)	28	....	1	0	7388	....	7388	....	....	....	
..	46	M. V	25	(? A)	60	....	1	0	3362	....	3362	....	....	....	
87	96	M. W	48	A	28	27.3	10	1	6789	6651	6709	....	....	....	
....	60	M. W	28	A	60	31.1	1	1	2658	...	2658	....	....	....	
58	59	M. W	26	A	60	31.5	2	2	3306	2663	2984.5	....	....	....	
97	99	M. V	26	A	60	33.5	3	2	3497	2498	2905	....	....	....	
	61	M. W	26	B	60	33	1	1	3009	....	3009	....	....	....	
71	74	M. W	26	C	28	19.4	4	1	3349	3264	3325	....	....	....	
100	104	M. W	26	C	28	18.8	5	0	3474	3280	3337	87	52	76.4	
62	78	M. W	26	C	60	31.5	9	4	3286	3185	3229.9	....	....	....	
105	109	M. W	26	C	60	34.9	5	1	3213	3105	3157.8	312	214	276.6	
67	82	M. W	48	C	28	27.7	7	2	7045	5614	6614.4	....	....	....	
83	86	M. W	48	C	60	49.5+	4	0	6711	6573	6622.2	....	....	....	
215	224	M. V	26	C	28	....	8	4	3401	2620	3113.8	73.3	(—)58.4	33	
175	227	M. V	26	C	60	....	5	1	3254	2722	3075	298	89	216.6	
122	126	E. V. P	52	C	28	27.2	5	0	6982	6502	6697	174	164	168.6	
127	131	E. V. F	52	C	60	50	5	0	6724	6496	6631.6	522	489	510.4	
134	138	K. H. C	52	C	28	27.4	5	2	6866	6726	6784.8	144	120	131	
139	143	K. H. C	52	C	60	49.9	5	4	6385	6422	6514.4	442	392	425.2	
154	158	O. B	52	C	60	50.2	5	0	6862	6652	6803.4	414	392	402.4	
159	162	O. C	52	C	28	26.1	4	2	6287	6031	6113	64	44	55.5	
163	167	O. C	52	C	60	47.3	5	1	6118	5836	5960.4	407	384	394.2	
228	230	M. V	26	Exp	28	....	3	1	Fired to try thin-lipped sabots.						
241	242	M. V	26	D	60	35	*2	0	Fired for Brazilian officers.						
110	114	M. V	26	C	28	....	5	0	3163	3104	3427	76	69	73.6	
115	119	M. V	26	C	60	....	5	0	3385	3252	3321	256	244	250	
178	187	M. V	26	C	28	....	10	2	3476	3092	3331.4	76	60	67.4	
178	186	M. V	26	C	28	....	9	0	3476	3264	3358	76	60	68.7	Same as above; rejecting shot tumbled.
188	197	M. V	26	C	60	....	9	2	3284	2160	3119	308	— 37	244.3	
188	197	M. V	26	C	60	....	7	0	3284	3188	3234.4	308	284	294.8	Do.
150	153	O. B	52	C	28	....	4	0	6992	6835	6934.5	29	26	27.75	
231	240	M. V	26	D	28	....	10	2*	3532	3460	3189.6	79.2	74.8	76.4	
246	255	O. V	52	D	28		10	2	7252	7001	7141.8	44	8	28.7	
256	264	O. V., No. 1	52	D	60	50.5	9	0	6992	6218	6484.2	580	481	519	
275	282	M. V	26	D	60	35.6+	8	0	3366	3155	3259.6	249	208	235.6	

*Eight shot; fair flight.

TABLE 17.—*Showing enlargement of bore and chamber of 12-inch muzzle-loading rifled mortar (cast iron, hooped with steel).*

Inches from muzzle.	Original diameter of bore.	Enlargement of bore—													
		After 7 rounds.	After 12 rounds.	After 25 rounds.	After 44 rounds.	After 63 rounds.	After 70 rounds.	After 86 rounds.	After 109 rounds.	After 119 rounds.	After 140 rounds.	After 170 rounds.	After 197 rounds.	After 304 rounds.	After 381 rounds.
88	12.006	+0.000	+0.000	+0.000	+0.001	+0.000	+0.001	+0.001	+0.000	+0.000	+0.000	+0.002	+0.002	+0.002	+0.002
87	12.006	.000	.001	.000	.001	.000	+0.001	.001	.000	.000	.000	.002	.002	.002	.002
86	12.006	.000	.000	-0.001	.001	.000	.000	.001	.000	.000	+0.001	.002	.002	.002	.002
85	12.006	.000	.000	.001	+0.000	.001	.000	+0.000	.000	.000	.001	+0.001	.001	.001	.001
84	12.006	.000	.000	.001	.000	.000	+0.001	.000	.000	.000	+0.000	.001	.001	.001	.001
83	12.006	.000	.000	.001	.000	.000	+0.000	.000	-0.001	.000	.000	+0.000	.000	.000	.001
82	12.006	.000	.000	.001	.000	.000	.000	-0.001	+0.000	.000	.000	.000	.000	.000	.001
81	12.006	.000	-0.001	.001	.000	.000	.000	+0.000	.000	.000	.000	.000	.001	.000	.000
80	12.006	.000	.001	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
79	12.006	.000	.001	.001	.000	-0.001	+0.001	.000	.000	.000	.000	.000	.000	.000	.000
78	12.006	.000	.001	.001	.000	.001	.001	.000	.000	.000	.000	.000	.000	.000	.000
77	12.006	.000	.001	.001	.000	+0.000	+0.000	.000	.000	.000	.000	.000	.000	.000	.000
76	12.006	.000	.001	.001	-0.001	.000	.000	-0.001	.001	.000	.000	.000	.000	.000	.000
75	12.006	.000	.001	.001	.001	.000	.000	.001	.000	-0.001	.000	.000	.000	.000	.000
74	12.006	.000	.001	.001	.001	.000	.000	.001	.000	.001	.000	.000	.000	.000	.000
73	12.006	-0.001	.001	.001	.001	.000	.000	.001	.000	.001	.000	.000	.000	.000	.000
72	12.006	+0.000	.001	.001	.001	.000	.000	.001	.000	.001	.000	.000	.000	.000	.000
71	12.006	.000	.001	.001	.001	.000	.000	.001	.000	.001	.000	-0.001	.000	.000	.000
70	12.006	.000	.001	.001	.001	.000	.000	.001	.000	.001	.000	+0.000	.000	.000	.000
69	12.006	.000	.001	.001	.001	.000	-0.001	.001	.000	.001	.000	.000	.000	.000	.000
68	12.006	.000	.001	-0.002	.001	.000	.001	.001	.000	.001	.000	.000	.000	.000	.000
67	12.006	-0.001	.001	.002	.001	.000	.001	.001	.000	.001	.000	.000	.000	.000	.000
66	12.006	.001	.001	-0.001	.001	.000	.001	+0.000	.000	.001	.000	.000	.000	.000	.000
65	12.006	.001	.001	.001	.001	-0.001	.001	.000	.000	.001	.000	.000	.000	.000	.000
64	12.006	.001	.001	.001	.001	.001	.001	.000	.000	.001	.000	.000	.000	.000	.000
63	12.006	.001	.001	.001	.001	+0.000	+0.000	.000	.000	.001	.000	.000	.000	.000	.000
62	12.006	.001	.001	.001	.001	.000	.000	.000	.000	.001	.000	.000	.001	.000	.000
61	12.006	.001	.001	.001	.001	.000	.000	.000	.000	.001	.000	.000	.001	.000	.000
60	12.006	.001	.001	.001	.001	.000	.000	.000	.000	.001	.000	.000	.001	.001	.000
58	12.006	.001	-0.002	.001	.001	.000	.000	.000	.000	.001	.000	.000	.001	.000	.000
56	12.006	-0.002	.002	.001	.001	.000	.000	+0.001	.000	.001	.000	.000	.001	.001	.000
54	12.006	-0.001	.002	.001	.001	.000	.000	.001	.000	.001	.000	.000	.001	.000	.000
52	12.007	.001	.002	.001	-0.002	.000	-0.001	+0.000	-0.001	-0.002	-0.001	-0.001	.000	-0.001	-0.001
50	12.007	.001	.002	.001	.002	.000	.001	.000	.001	.002	.001	.001	.000	-0.001	-0.001
48	12.007	+0.000	.002	.001	.002	.000	.001	-0.001	.001	-0.001	.001	.001	.000	.000	.000
46	12.007	.000	.002	.001	.002	.000	.001	.001	.001	.001	.001	+0.000	.000	.000	.000
44	12.007	.000	-0.001	.001	.002	+0.001	.001	.001	.001	.001	+0.000	.000	.000	.000	.000
42	12.007	.000	.001	.001	.002	.001	+0.000	.001	+0.000	.001	.000	.000	.000	.000	.000
40	12.007	.000	.001	.001	.002	.001	.000	.001	.000	.001	.000	.000	.000	.000	000
38	12.007	.000	.001	.001	-0.001	.001	.000	+0.000	.000	.001	.000	.000	.000	.000	+0.001
36	12.008	-0.001	-0.002	.001	-0.002	+0.000	-0.001	-0.001	-0.001	-0.002	-0.001	.000	.000	-0.001	.000

34	12.008	+0.000	.002	.001	.002	.000	.001	.001	+0.000	.002	+0.000	.000	.000	−0.001	.000
32	12.008	.000	.002	−0.002	.002	.000	.001	.001	.000	.002	.000	.000	.000	.000	.000
30	12.008	.000	.002	.002	.002	.000	.001	.001	.000	.002	.000	.000	.000	.000	.000
28	12.008	.000	.002	.002	−0.002	.000	.001	.001	.000	.002	.000	+0.001	.000	.000	.000
26	12.007	+0.001	+0.000	−0.001	−0.002	+0.002	+0.001	+0.000	+0.001	−0.001	+0.001	+0.002	.001	+0.001	.001
24	12.007	.001	.000	+0.000	.002	.002	.001	.000	.001	.001	.001	.002	.001	.001	.001
22	12.007	.001	.000	.000	.002	.002	.001	.000	.001	.001	.001	.002	.001	.001	.001
20	12.007	.001	.000	+0.001	.002	.002	.001	.000	.001	+0.000	.001	.002	.001	.001	.002
18	12.007	.001	+0.001	.001	−0.001	.002	.001	+0.001	.001	.000	.001	.002	.001	.001	.002
16	12.007	.001	.001	.001	.001	.002	.001	.001	.001	.000	+0.002	.002	.002	.002	.002
14	12.007	+0.003	.001	.001	.001	.002	.001	.001	+0.002	.000	.002	.002	.002	.002	.002
12	12.007	+0.002	.001	.001	.001	.002	.001	.001	.002	.000	.002	+0.003	.002	.002	.002
10	12.007	+0.003	.001	.001	+0.001	.002	.001	.001	+0.001	+0.001	.002	.003	.003	.003	.003
8	12.007	.003	+0.002	.001	+0.002	.002	.001	.001	+0.002	.001	.002	.003	.003	.008	.003
6	12.007	.003	.002	.001	.002	.002	.001	+0.002	.002	.001	+0 003	.003	.003	.003	.003
4	12.009	+0.001	+0.000	−0.001	+0.001	+0.001	+0.000	+0.000	+0.000	−0.001	+0.001	+0.001	.001	.001	.001
2	12.011	+0.000	−0.002	.001	+0.002	−0.001	−0.002	−0.002	−0.001	−0.002	−0.001	−0.001	−0.001	−0.001	−0.001
1	12.012	+0.002	−0.001	−0.002	+0.000	−0.002	−0.002	−0.002	−0.002	−0.003	−0.002	−0.002	−0.002	−0.002	−0.001
							Chamber—ring used, diameter 11″.85.								
101	11.848	These measurements of original diameter were made at South Boston Foundry.								+0.005	+0.005	+0.005	+0.005	+0.005	+0.005
100	.848									.005	.005	.005	.005	.005	.005
99	.848									.005	.005	.005	.005	.005	.005
98	.848									.005	.005	.005	.005	.005	.004
97	.848									.005	.005	.005	.004	.004	.004
96	.848									.005	.005	.005	.004	.004	.004
95	.848									.005	.005	.005	.004	.004	.004
94	.848									.005	.005	.005	.004	.004	.004
93	.848									.005	.005	.005	.004	.004	.004

Record of firing with 12-inch muzzle-loading rifled mortar at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure, per square inch of bore (Rodman).	Instrumental velocity 90′ from muzzle.	Recoil.	Wind—strength and direction.
		1885.							° ′	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 29.947; thermometer, 81.3; humidity, 52.	45	July 15	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..	Eureka shell.	610	..	28	......	......	5.33	From front and right 45°; 12 miles an hour.
	46	July 15	Du Pont's hexagonal M. V. Density, 1.700; granulation, 72.	25	..		610	..	60	......	......	1.67	
	47	July 15		48	..		610	..	41	......	......	4.83	
A. M.—Barometer, 30.216; thermometer, 80.2; humidity, 79.	48	July 23	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..		610	..	28	30,750	......	5.42	From front and right 45°; 18 miles an hour.
A. M.—Barometer, 29.735; thermometer, 77; humidity, 83.	49	Sept. 9		26	..		610	..	−8	9,000	......	5.71	From front and right 48°; 13 miles an hour.
	50	Sept. 9		26	..		610	..	−5	10,000	646	5.67	
	51	Sept. 9		26	..		610	..	−5	9,500	655	5.33	
											115′		
	52	Sept. 9		45	..		610	..	−8	24,750	923	5.71	
	53	Sept. 9		47	..		610	..	−8	22,500	951	5.54	
	54	Sept. 9		48	..		610	..	−8	26,250	957	5.54	
											90′		
P. M.—Barometer, 29.697; thermometer, 76; humidity, 85.	55	Sept. 9	Du Pont's hexagonal M. V. Density, 1.700; granulation, 72.	26	..		610	..	−5	12,500	681	4.67	From front and left 43°; 10 miles an hour.
	56	Sept. 9		26	..		610	..	−5	12,500	637	4.58	
	57	Sept. 9		26	..		610	..	−5	11,500	672	4.58	
	58	Sept. 9	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	26	..		610	..	60	......	......	1.50	From front, 10 miles an hour.
	59	Sept. 9		26	..		610	..	60	......	......	1.50	
	60	Sept. 9		28	..		610	..	60	......	......	1.58	
	61	Sept. 9		26	..		610	..	60	......	......	1.50	
	62	Sept. 9		26	..		610	..	60	......	......	1.50	
	63	Sept. 9		26	..		610	..	60	......	......	1.50	

Hook, N. J., from July 15, 1885, *to October* 16, 1886.

Kind of sabot.	Time of flight.	Ranges.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.	
	Secs.	*Yds.*		
......	......	7,388	Fired over water	Good flight.
......	......	3,362		Do.
......	......	Lost.		Do.
......	......	......		Do.
A	......	......	Fired into sand butt	
A	......	......		
A	......	......		One gallon of oil put in cylinder. Sabot recovered; marks of rifling not well defined.
A	......	......		One gallon of oil put in cylinder.
A	......	......		Do.
A	......	......		
A	......	......		
A	......	......		Top carriage bound on right guide and failed to run back into battery.
A	......	......		
A	Lost.	3,306	Fired to sea for range	The first part of flight good; remainder probably irregular.
A	31½	2,663		Projectile tumbled.
A	31½	2,658		Do.
B	33	3,009		Do.
C	35	3,194		Good flight.
C	35½	3,278		Do.

Record of firing with 12-inch muzzle-loading rifled mortar at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure, per square inch of bore.	Instrumental velocity.	Recoil.	Wind—strength and direction.
		1885.							° ′	*Lbs.*	*Feet.*	*Feet.*	
A. M.—Barometer, 29.979; thermometer, 61; humidity, 93.	64	Sept. 10	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	26	..	Eureka shell.	610	..	60	......	......	1.42	From rear and left 87°; 23 miles an hour.
A. M.—Barometer, 29.979; thermometer, 61; humidity, 93.	65	Sept. 10	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	26	..	Eureka shell.	610	..	60	....	......	1.42	From rear and left 87°; 23 miles an hour.
A. M.—Barometer, 29.979; thermometer, 61; humidity, 93.	66	Sept. 10	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	26	..	Eureka shell.	610	..	60	......	......	1.42	From rear and left 87°; 23 miles an hour.
A. M.—Barometer, 29.979; thermometer, 61; humidity, 93.	67	Sept. 10	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..	Eureka shell.	610	..	28	......	......	4.92	From rear and left 87°; 23 miles an hour.
A. M.—Barometer, 29.979; thermometer, 61; humidity, 93.	68	Sept. 10	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..	Eureka shell.	610	..	28	......	......	5.16	From rear and left 87°; 23 miles an hour.
A. M.—Barometer, 29.979; thermometer, 61; humidity, 93.	69	Sept. 10	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..	Eureka shell.	610	..	28	......	......	5.16	From rear and left 87°; 23 miles an hour.
A. M.—Barometer, 29.979; thermometer, 61; humidity, 93.	70	Sept. 10	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..	Eureka shell.	610	..	—5	......	......	5.50	From rear and left 87°; 23 miles an hour.
A. M.—Barometer, 30.256; thermometer, 65; humidity, 82.	71	Sept. 12	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	26	..	Eureka shell.	610	..	28	....	......	4.08	From rear, 4 miles an hour.
A. M.—Barometer, 30.256; thermometer, 65; humidity, 82.	72	Sept. 12	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	26	..	Eureka shell.	610	..	28	......	......	4.00	From rear, 4 miles an hour.
A. M.—Barometer, 30.256; thermometer, 65; humidity, 82.	73	Sept. 12	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	26	..	Eureka shell.	610	..	28	......	......	3.92	From rear, 4 miles an hour.
P. M.—Barometer, 29.818; thermometer, 82.4; humidity, 65.	74	Sept. 15	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	26	..	Eureka shell.	610	..	28	....	......	4.08	From rear, 17 miles an hour.
P. M.—Barometer, 29.818; thermometer, 82.4; humidity, 65.	75	Sept. 15	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	26	..	Eureka shell.	610	..	60	......	......	1.42	From rear, 17 miles an hour.
P. M.—Barometer, 29.818; thermometer, 82.4; humidity, 65.	76	Sest. 15	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	26	..	Eureka shell.	610	..	60	......	......	1.42	From rear, 17 miles an hour.
P. M.—Barometer, 29.818; thermometer, 82.4; humidity, 65.	77	Sept. 15	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	26	..	Eureka shell.	610	..	60	......	......	1.42	From rear, 17 miles an hour.
P. M.—Barometer, 29.818; thermometer, 82.4; humidity, 65.	78	Sept. 15	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	26	..	Eureka shell.	610	..	60	......	......	1.42	From rear, 17 miles an hour.
A. M.—Barometer, 29.913; thermometer, 72.5; humidity, 58.	79	Sept. 16	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..	Eureka shell.	610	..	28	......	....	4.33	From rear, 21 miles an hour.
A. M.—Barometer, 29.913; thermometer, 72.5; humidity, 58.	80	Sept. 16	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..	Eureka shell.	610	..	28	......	......	4.33	From rear, 21 miles an hour.
A. M.—Barometer, 29.913; thermometer, 72.5; humidity, 58.	81	Sept, 16	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..	Eureka shell.	610	..	28	......	......	4.42	From rear, 21 miles an hour.
A. M.—Barometer, 29.913; thermometer, 72.5; humidity, 58.	82	Sept. 16	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..	Eureka shell.	610	..	28	......	......	4.33	From rear, 21 miles an hour.
A. M.—Barometer, 29.913; thermometer, 72.5; humidity, 58.	83	Sept. 16	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..	Eureka shell.	610	..	60	......	....	2.75	From rear, 21 miles an hour.
A. M.—Barometer, 29.913; thermometer, 72.5; humidity, 58.	84	Sept. 16	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..	Eureka shell.	610	..	60	......	......	2.58	From rear, 21 miles an hour.
A. M.—Barometer, 29.913; thermometer, 72.5; humidity, 58.	85	Sept. 16	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..	Eureka shell.	610	..	60	......	......	2.58	From rear, 21 miles an hour.
A. M.—Barometer, 29.913; thermometer, 72.5; humidity, 58.	86	Sept. 16	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..	Eureka shell.	610	..	60	......	......	2.58	From rear, 21 miles an hour.
A. M.—Barometer, 30.216; thermometer, 49; humidity, 76.	87	Oct. 7	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..	Eureka shell.	610	..	28	......	......	5.25	From rear, 11 miles an hour.
A. M.—Barometer, 30.216; thermometer, 49; humidity, 76.	88	Oct. 7	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..	Eureka shell.	610	..	28	......	......	5.42	From rear, 11 miles an hour.
A. M.—Barometer, 30.216; thermometer, 49; humidity, 76.	89	Oct. 7	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..	Eureka shell.	610	..	28	......	......	5.42	From rear, 11 miles an hour.
A. M.—Barometer, 30.216; thermometer, 49; humidity, 76.	90	Oct. 7	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..	Eureka shell.	610	..	28	......	......	5.42	From rear, 11 miles an hour.
A. M.—Barometer, 30.216; thermometer, 49; humidity, 76.	91	Oct. 7	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..	Eureka shell.	610	..	28	....	......	5.42	From rear, 11 miles an hour.
A. M.—Barometer, 30.216; thermometer, 49; humidity, 76.	92	Oct. 7	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..	Eureka shell.	610	..	28	......	......	5.42	From rear, 11 miles an hour.
A. M.—Barometer, 30.216; thermometer, 49; humidity, 76.	93	Oct. 7	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..	Eureka shell.	610	..	28	......	......	5.42	From rear, 11 miles an hour.
A. M.—Barometer, 30.216; thermometer, 49; humidity, 76.	94	Oct. 7	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..	Eureka shell.	610	..	28	......	......	5.42	From rear, 11 miles an hour.
A. M.—Barometer, 30.216; thermometer, 49; humidity, 76.	95	Oct. 7	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..	Eureka shell.	610	..	28	......	......	5.42	From rear, 11 miles an hour.
A. M.—Barometer, 30.216; thermometer, 49; humidity, 76.	96	Oct. 7	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..	Eureka shell.	610	..	28	......	......	5.42	From rear, 11 miles an hour.
A. M.—Barometer, 30.216; thermometer, 49; humidity, 76.	97	Oct. 7	Du Pont's hexagonal M. V. Density, 1.700; granulation, 72.	26	..	Eureka shell.	610	..	60	......	......	1.42	From rear, 11 miles an hour.
A. M.—Barometer, 30.216; thermometer, 49; humidity, 76.	98	Oct. 7	Du Pont's hexagonal M. V. Density, 1.700; granulation, 72.	26	..	Eureka shell.	610	..	60	......	......	1.42	From rear, 11 miles an hour.
A. M.—Barometer, 30.216; thermometer, 49; humidity, 76.	99	Oct. 7	Du Pont's hexagonal M. V. Density, 1.700; granulation, 72.	26	..	Eureka shell.	610	..	60	......	......	1.42	From rear, 11 miles an hour.

***Hook, N. J., from July* 15, 1885, *to October* 16, 1886—Continued.**

Kind of sabot.	Time of flight.	Ranges.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.	
	Secs.	*Yds.*		
C	34¼	3,185		Good flight.
C	34¾	3,224		Slightly irregular flight.
C	34⅛	3,236	Fired to sea for range......	Good flight.
C	24⅞	5,614		Do.
C	Lost.	6,802		Do.
C	28	6,452		Fair flight.
C	......	......	Fired into butt to try sabot.	
C	20	3,349		Flight good (probably slow in taking time).
C	19¼	3,346		Fair flight; slight flutter.
C	19½	3,340		Flight good.
C	19	3,264		Good flight.
C	34	3,265		Flight wavy and irregular.
C	34¼	3,294		Flight slightly irregular.
C	34½	3,197		Flight fair.
C	34¾	3,286		Flight good.
C	28½	7,019		Do.
C	28¾	7,045		Do.
C	27	6,607		Flight fluttering; shell stuck in bore and seated with difficulty.
C	27⅞	6,762		Flight good.
C	49¾	6,711		Do.
C	49¼	6,607		Do.
C	49¾	6,598		Do.
C	49½	6,573	Fired to sea for range......	Do.
A	27¼	6,663		Do.
A	27¾	6,708		Do.
A	27⅞	Lost.		Do.
A	27¼	6,789		Do.
A	27½	6,766		Do.
A	27½	6,738		Do.
A	27½	6,651		Do.
A	27	6,679		Slightly irregular.
A	27½	6,711		Good flight.
A	26⅞	6,679		Do.
A	31⅞	2,720		Shot tumbled.
A	35¼	3,497		Good flight. Shell stuck in bore and had to be driven home.
A	Lost.	2,498		Shot tumbled.

Record of firing with 12-inch muzzle-loading rifled mortar at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (Rodman).	Instrumental velocity 90' from muzzle.	Recoil.	Wind—strength and direction.
		1885.							° ′	*Lbs.*	*Feet.*	*Feet.*	
A. M.—Barometer, 30.060; thermometer, 47.3; humidity, 66.	100	Nov. 11	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	26	..	Eureka shell altered to C sabot.	610	..	28	......	......	4.50	From rear, 20 miles an hour.
	101	Nov. 11		26	..		610	..	28	......	......	4.50	
	102	Nov. 11		26	..		610	..	28	......	......	4.67	
	103	Nov. 11		26	..		610	..	28	......	......	4.67	
	104	Nov. 11		26	..		610	..	28	......	......	4.67	
	105	Nov. 11		26	..		610	..	60	......	......	1.33	
	106	Nov. 11		26	..		610	..	60	......	......	1.42	
	107	Nov. 11		26	..		610	..	60	......	......	1.33	
	108	Nov. 11		26	..		610	..	60	......	......	1.33	
	109	Nov. 11		26	..		610	..	60	......	......	1.33	
P. M.—Barometer, 29.972; thermometer, 55; humidity, 52.	110	Nov. 11	Du Pont's hexagonal M. V. Density, 1.700; granulation, 72.	26	..		610	..	28	......	......	4.58	From right, 15 miles an hour.
	111	Nov. 11		26	..		610	..	28	......	......	4.58	
	112	Nov. 11		26	..		610	..	28	......	......	4.58	
	113	Nov. 11		26	..		610	..	28	......	......	4.58	
	114	Nov. 11		26	..		610	..	28	......	......	4.58	
	115	Nov. 11		26	..		610	..	60	......	......	1.42	
	116	Nov. 11		26	..		610	..	60	......	......	1.42	
	117	Nov. 11		26	..		610	..	60	......	......	1.50	
	118	Nov. 11		26	..		610	..	60	......	......	1.50	
	119	Nov. 11		26	..		610	..	60	......	......	1.50	
			Du Pont's hexagonal E. V. F. Density, 1.750; granulation, 72.								139′ 8″		
A. M.—Barometer, 29.871; thermometer, 56.4; humidity, 75.	120	Nov. 12		52	..		610	..	—5	2,500	970	5.79	From rear and right, 87°; 20 miles an hour.
	121	Nov. 12		52	..		610	..	—8	2,500	986	5.79	
P. M.—Barometer, 29.801; thermometer, 63.7; humidity, 60.	122	Nov. 12		52	..		610	..	28	......	......	5.33	From right, 24 miles an hour.
	123	Nov. 12		52	..		610	..	28	......	......	5.42	
	124	Nov. 12		52	..		610	..	28	......	......	5.67	
	125	Nov. 12		52	..		610	..	28	......	......	5.42	
	126	Nov. 12		52	..		610	..	28	......	......	5.42	
	127	Nov. 12		52	..		610	..	60	......	......	2.50	
	128	Nov. 12		52	..		610	..	60	......	......	2.50	
	129	Nov. 12		52	..		610	..	60	......	......	2.33	
	130	Nov. 12		52	..		610	..	60	......	......	2.25	
	131	Nov. 12		52	..		610	..	60	......	......	2.25	

Hook, N. J., from July 15, 1885, to October 16, 1886—Continued.

Time of flight.	Kind of sabot.	Ranges.	Deflection to right.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.		
Secs.		*Yds.*	*Yds.*			
18⅞	C	3, 254	76	Fired over water for range.	Good flight.	All these flights were probably good, the flutter being due possibly to inequality in the surface of sabot.
18⅝	C	3, 280	81		Do.	
19	C	3, 474	52		Do.	
18⅝	C	3, 332	86		Do.	
18¾	C	3, 345	87		Do.	
35	C	3, 179	214		Very slight flutter.	
34¾	C	3, 130	287		Good flight.	
35¼	C	3, 213	284		Do.	
34¾	C	3, 162	286		Do.	
34¾	C	3, 105	312		Do.	
19	C	3, 412	74		Do.	
19¼	C	3, 463	75		Good flight. Projectile stuck in bore and rammed home with difficulty.	
19⅓	C	3, 422	69		Good flight.	
19¼	C	3, 434	76		Do.	
19⅜	C	3, 404	74		Do.	
36	C	3, 385	256		Do.	
35½	C	3, 252	247		Do.	
35¾	C	3, 303	246		Do.	
35⅞	C	3, 313	244		Do.	
35⅝	C	3, 852	256		Do.	
......	C	......	......	Fired into sand butt.		
......	C	......	......			
26¾	C	6, 502	172	Fired over water for range.	Good flight.	
26⅞	C	6, 689	164		Do.	
27⅜	C	6, 657	165		Good flight. Projectile stuck in bore and seated with difficulty.	
27⅜	C	6, 653	168		Good flight.	
27¾	C	6, 982	174		Do.	
50⅞	C	6, 643	521		Do.	
49⅞	C	6, 681	501		Do.	
49½	C	6, 496	489		Do.	
49⅞	C	6, 724	519		Do.	
49⅞	C	6, 614	522		Do.	

Record of firing with 12 inch muzzle-loading rifled mortar at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (Rodman).	Instrumental velocity 139'.5'' from muzzle.	Recoil.	Wind—strength and direction.
		1885.							° '	*Lbs.*	*Feet.*	*Feet.*	
A. M.—Barometer, 29.736; thermometer, 60.8; humidity, 79.	132	Nov. 13	Du Pont's sphero-hexagonal K. H. C. Density, 1.775; granulation, 123.	52	..	Eureka shell altered to C sabot.	610	..	—20	25, 500	1, 000	5. 42	From front and right, 45°; 24 miles an hour.
	133	Nov. 13		52	.		610	..	—22	24, 800	984	5. 75	
	134	Nov. 13		52	..		610	..	28	......	......	5. 42	From right, 12 miles an hour.
	135	Nov. 13		52	..		610	..	28	......	......	5. 42	
	136	Nov. 13		52	..		610	..	28	....	....	5. 42	
	137	Nov. 13		52	..		610	..	28	......	.....	5. 42	
	138	Nov. 13		52	..		610	..	28	...	....	5. 42	
	139	Nov. 13		52	..		610	..	60	......	....	2. 25	
	140	Nov. 13		52	..		610	..	60	......	.....	2. 25	
	141	Nov. 13		52	..		610	..	60	......	......	2. 25	
	142	Nov. 13		52	.		610	..	60	......	.....	2. 25	
	143	Nov. 13		52	..		610	..	60	......	......	2. 25	
P. M.—Barometer, 29.616; thermometer, 50.2; humidity, 87.	144	Nov. 19	Du Pont's hexagonal M. V. Density, 1.700; granulation, 72.	26	..		610	..	60	8, 100	......	1. 25	From rear and left, 45°; 31 miles an hour.
	145	Nov. 19	Du Pont's sphero-hexagonal K. H. C. Density, 1.775; granulation, 123.	52	..		610	..	60	20, 250	......	5. 50	
A. M.—Barometer, 30.136; thermometer, 36.6; humidity, 82.	146	Jan. 27	Du Pont's sphero-hexagonal O. B. Density, 1.725; granulation, 123.	52	..		610	..	—10	25, 250	983	4. 50	From front and left, 87°; 25 miles an hour.
	147	Jan. 27		52	..		610	..	......	25, 250	986	5. 25	
	148	Jan. 27	Du Pont's sphero-hexagonal O. C. Density, 1.750; granulation, 123.	52	..		610	..	......	20, 250	943	5. 16	
	149	Jan. 27		52	..		610	..	......	19, 250	936	5. 08	

Hook, N. J., from July 15, 1885, to October 16, 1886—Continued.

Time of flight.	Kind of sabot.	Ranges.	Deflection to right.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.		
Secs.		*Yds.*	*Yds.*			
......	C	......	......	Fired into sand butt.		
......	C	......	......			
27⅗	C	6,866	120	Fired over water for range.	Good flight.	All of these flights were probably good, the flutter being due possibly to inequality in surface of sabot.
27½	C	6,813	121		Fluttering flight.	
27⅓	C	6,726	134		Good flight.	
27⅗	C	6,728	136		Do.	
Lost.	C	6,791	144		Slightly fluttering flight.	
49⅞	C	6,422	413		Fluttering flight.	
50¼	C	6,529	442		Slightly fluttering flight.	
50	C	6,528	440		Fluttering flight.	
49⅞	C	6,508	439		Slightly fluttering flight.	
49¾	C	6,585	392		Good flight.	
					Mortar star-gauged after 109th and 119th rounds.	
35⅜	C	3,207	298		Good flight.	
Lost.	C	6,466	614		Good flight.	
......	C	......	......	Fired into sand butt to try powder.		
......	C	......	......			
......	C	......	......			
......	C	......	......			

Record of firing with 12-inch muzzle-loading rifled mortar at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Lbs.	Powder. Wgt. Ozs.	Projectile. Kind.	Projectile. Wgt. Lbs.	Projectile. Wgt. Ozs.	Elevation.	Pressure per square inch of bore (Rodman).	Instrumental velocity 115½' from muzzle.	Recoil.	Wind—strength and direction.
		1886.							° '	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 30.108; thermometer, 42; humidity, 57.	150	Feb. 9	Du Pont's sphero-hexagonal O. B. Density, 1.725; granulation, 123.	52	..	Eureka shell. Altered to C sabot.	610	..	28	......	......	4.25	From front and right, 7°; 12 miles an hour.
	151	Feb. 9		52	..		610	..	28	......	......	4.00	
	152	Feb. 9		52	..		610	..	28	......	......	4.00	
	153	Feb. 9		52	..		610	..	28	......	......	4.00	
	154	Feb. 9		52	..		610	..	60	......	......	2.33	
	155	Feb. 9		52	..		610	..	60	......	......	2.33	
	156	Feb. 9		52	..		610	..	60	......	......	2.16	
	157	Feb. 9		52	..		610	..	60	......	......	2.16	
	158	Feb. 9		52	..		610	..	60	......	......	2.08	
	159	Feb. 9	Du Pont's sphero-hexagonal O. C. Density, 1.750; granulation, 123.	52	..		610	..	28	......	......	3.75	
	160	Feb. 9		52	..		610	..	28	......	......	3.75	
	161	Feb. 9		52	..		610	..	28	......	......	3.67	
	162	Feb. 9		52	..		610	..	28	......	......	3.67	
	163	Feb. 9		52	..		610	..	60	......	......	2.00	
	164	Feb. 9		52	..		610	..	60	......	......	2.00	
	165	Feb. 9		52	..		610	..	60	......	......	2.00	
	166	Feb. 9		52	..		610	..	60	......	......	1.92	
	167	Feb. 9		52	..		610	..	60	......	......	1.92	
											90' 7''		
P. M.—Barometer, 30.250; thermometer, 48; humidity, 78.	168	Mar. 17	Du Pont's hexagonal M. V. Density, 1.700; granulation, 72; sample.	26	..		610	..	−8	9,500	640	.....	From front and right, 45°; 6 miles an hour.
	169	Mar. 17		26	..		610	..	−5	9,750	670	.....	
A. M.—Barometer, 30.240; thermometer, 35; humidity, 72.	170	Mar. 18		25	..		610	..	−5	8,750	624	.....	From rear and left, 30°; 4 miles an hour.
	171	Apr. 2		25	..		610	..	−2	10,250	672	1.33	From rear and right, 87°; 20 miles an hour.
	172	Apr. 2		25	..		610	..	−2	10,600	646	1.08	
											115' 7''		
P. M.—Barometer, 30.000; thermometer, 50; humidity, 58.	173	Apr. 2	O. B. A., No. 1. Du Pont's sphero-hexagonal. Density, 1.725; granulation, 123.	52	..		610	..	−5	28,500	1,014	4.50	
	174	Apr. 2	O. B. A., No. 2.	52	..		610	..	−5	31,500	1,021	4.16	

Hook, N. J., from July 15, 1885, *to October* 16, 1886—**Continued.**

Time of flight.	Sabot.	Ranges.	Deflection to right.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.	
Secs.		*Yds.*	*Yards.*			
27⅝	C	6,835	26	Fired over water to obtain range and try powder.	Good flight.	
27¾	C	6,953	28		Do.	
27⅞	C	6,958	29		Do.	
28	C	6,992	28		Do.	
50¼	C	6,804	392		Do.	
50	C	6,844	392		Do.	
50¼	C	6,755	405		Do.	
50¼	C	6,752	414		Do.	
50⅛	C	6,862	400		Do.	Rounds 150 to 167, inclusive, fired in 2½ hours.
25¾	C	6,066	61		Do.	
26¼	C	6,031	44		Do.	
26¾	C	6,068	53		Flight not perfectly smooth.	
26⅛	C	6,287	64		Do.	
47⅜	C	5,836	384		Good flight.	
47¾	C	5,883	397		Do.	
47¼	C	6,118	394		Do.	
47⅛	C	5,888	389		Do.	
47⅝	C	6,077	407		Projectile stuck in bore and seated with difficulty. Slightly fluttering flight.	
......	C	......	....	Fired into sand butt to try powder.		
......	C	......	....			
......	C	......	....			
......	C	......	....			
......	C	....	....			
......	C	......	....			
......	C	......	....			

Record of firing with 12-inch muzzle-loading rifled mortar at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Lbs.	Powder. Wgt. Ozs.	Projectiles. Kind.	Projectiles. Wgt. Lbs.	Projectiles. Wgt. Ozs.	Elevation.	Pressure per square inch of bore (Rodman).	Instrumental velocity 115′ 7″ from muzzle.	Recoil.	Wind—strength and direction.
		1886.							° ′	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 30.200; thermometer, 56; humidity, 74.	175	Apr. 20	Du Pont's hexagonal M. V. Density, 1.700; granulation, 72.	26	..	Eureka shell. Altered to C sabot.	610	..	60	......	......	1.33	From front and left, 80°; 12 miles an hour.
	176	Apr. 20		26	..		610	..	60	......	......	1.33	
	177	Apr. 20		26	..		610	..	60	......	......	1.33	
A. M.—Barometer, 30.040; thermometer, 69; humidity, 57.	178	Apr. 22		26	..		610	..	28	......	......	....	From rear and right, 45°; 6 miles an hour.
	179	Apr. 22		26	..		610	..	28	......	......	....	
	180	Apr. 22		26	..		610	..	28	......	......	....	
	181	Apr. 22		26	..		610	..	28	......	......	....	
	182	Apr. 22		26	..		610	..	28	......	......	....	
	183	Apr. 22		26	..		610	..	28	......	......	....	
	184	Apr. 22		26	..		610	..	28	......	......	....	
	185	Apr. 22		26	..		610	..	28	......	......	....	
	186	Apr. 22		26	..		610	..	28	......	......	....	
	187	Apr. 22		26	..		610	..	28	......	......	....	
	188	Apr. 22		26	..		610	..	60	......	......	....	
	189	Apr. 22		26	..		610	..	60	......	......	....	
	190	Apr. 22		26	..		610	..	60	......	......	....	
	191	Apr. 22		26	..		610	..	60	......	......	....	
	192	Apr. 22		26	..		610	..	60	......	......	....	
	193	Apr. 22		26	..		610	..	60	......	......	....	
	194	Apr. 22		26	..		610	..	60	......	......	....	
	195	Apr. 22		26	..		610	..	60	......	......	....	
	196	Apr. 22		26	..		610	..	60	......	......	....	
	197	Apr. 22		26	..		610	..	60	......	......	....	
A. M.—Barometer, 29.846; thermometer, 75; humidity, 48.	198	May 5	Du Pont's O. U. Density, 1.725; granulation, 100.	52	..		610	..	— 5	32,000	1,012	6.16	From front and right, 48°; 12 miles an hour.
	199	May 5		52	..		610	..	—10	28,500	1,018	6.16	
	200	May 5	Du Pont's O. V. Density, 1.750; granulation, 100.	52	..		610	..	—15	18,750	979	6.16	
	201	May 5		52	..		610	..	—15	25,750	987	6.16	
	202	May 5	Du Pont's O. W. Density, 1.725; granulation, 123.	52			610	..	—20	31,000	1,011	6.16	
	203	May 5	Du Pont's O. V. Density, 1.750; granulation, 100.	52	..		610	..	—20	25,750	984	6.16	

Hook, N. J., from July 15, 1885, *to October* 16, 1886—Continued.

Sabot.	Time of flight.	Ranges.	Deflection.			Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
	Secs.	*Yds.*	*Yards.*			
C	......	3, 054	221	right.	Fired down beach to observe method in which projectiles strike ground.	Struck with point in line of trajectory.
C	......	2, 722	89	right.		Base wabbling, but struck with point in line of trajectory.
C	......	3, 138	241	right.		Struck with point in line of trajectory.
C	21	3, 264	64	right.	Fired over water for ranges.	Slightly fluttering flight. (Recorded time possibly too great).
C	19⅝	3, 348	76	right.		Good flight.
C	19⅝	3, 296	69	right.		Do.
C	19⅝	3, 424	72	right.		Do.
C	19¾	3, 476	60	right.		Do.
C	19	3, 318	66	right.		Do.
C	18⅝	3, 328	70	right.		Do.
C	19⅝	3, 408	72	right.		Do.
C	19¼	3, 360	69	right.		Do.
C	19	3, 092	56	right.		Shell tumbled.
C	38	3, 236	284	right.		Good flight. (Recorded time probably too great.)
C	35⅝	3, 284	304	right.		Good flight.
C	34⅝	3, 201	284	right.		Do.
C	35	3, 188	296	right.		Do.
C	34⅞	3, 240	284	right.		Do.
C	32⅞	2, 972	136	right		Very irregular flight. Tumbled.
C	32	2, 460	37	left.		Do.
C	34⅜	3, 284	304	right.		Good flight.
C	35¼	Lost.	....			Do.
C	34¾	8, 208	308	right.		Do.
C	......	....	....		Fired into sand butt to try powder.	
C	......	....	....			
C	......	....	....			
C	......	....	....			
C	......	....	....			
C	......	....	....			

Record of firing with 12-inch muzzle-loading rifled mortar at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (Rodman).	Instrumental velocity 115 feet from muzzle.	Recoil.
		1886.							° ′	*Lbs.*	*Feet.*	*Feet.*
A. M.—Barometer, 29.920; thermometer, 63; humidity, 100.	204	June 16	Du Pont's sphero-hexagonal. Density, 1.795; granulation, 100. O.X.	52	..	Eureka shell.	610	..	— 5	19,000	956	5.33
	205	June 16	O.X.	52	..		610	..	— 5	21,250	961	5.33
	206	June 16	Density, 1.750; granulation, 100. O.V. No. 1	52	..		610	..	—15	27,250	1,001	5.33
	207	June 16	O.V. No. 1	52	..		610	..	—15	25,000	997	5.37
	208	June 16	O.V. No. 2	52	..		610	..	—15	28,500	1,003	5.50
	209	June 16	O.V. No. 2	52	..		610	..	—15	25,250	1,003	5.50
	210	June 16	O.V. No. 1	52	..		610	..	—15	28,250	998	5.50
	211	June 16	O.V. No. 2	52	..		610	..	—15	27,750	1,001	5.50
	212	June 16	Density, 1.795; granulation, 100. O.X.	52	..		610	..	—15	15,750	957	5.50
										Small Crusher gauge.		
P. M.—Barometer, 29.920; thermometer, 63; humidity, 100.	213	June 16	Density, 1.750; granulation, 100. O.V. No. 1	52	..		610	..	—15	26,300	989	5.50
	214	June 16	O.V. No. 2	52	..		610	..	—15	28,400	1,003	5.50
P. M.—Barometer, 29.800; thermometer, 78; humidity, 82.	215	July 15	Du Pont's M. V. Density, 1.700; granulation, 72. (Hexagonal.)	26	..		610	..	28	......	......	4.16
	216	July 15		26	..		610	..	28	......	......	4.16
	217	July 15		26	..		610	..	28	......	......	4.25
	218	July 15		26	..		610	..	28	......	......	4.25
	219	July 15		26	..		610	..	28	......	......	4.25
	220	July 15		26	..		610	..	28	......	......	4.25
	221	July 15		26	..		610	..	28	......	......	4.25
	222	July 15		26	..		610	..	28	......	......	4.25
	223	July 15		26	..		610	..	28	......	......	4.25
	224	July 15		26	..		610	..	28	......	......	4.25
	225	July 15		26	..		610	..	60	......	......	1.67
	226	July 15		26	..		610	..	60	......	......	1.67
	227	July 15		26	..		610	..	60	......	......	1.67
A. M.—Barometer, 29.850; thermometer, 72; humidity, 90.	228	July 16		26	..		610	..	28	......	......	4.42
	229	July 16		26	..		610	..	28	......	......	4.42
	230	July 16		26	..		610	..	28	......	......	4.42

Hook, N. J., from July 15, 1885, to October 16, 1886—Continued.

Wind, strength and direction.	Kind of sabot.	Time of flight.	Ranges.	Deflection.	No. of pressure plug.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
		Secs.	*Yds.*	*Yards.*			
From rear and left, 48°; 4 miles an hour.	C	......	......	....	2	Fired into sand butt to try powders.	
	C	......	......	....	1		
	C	......	......	....	2		
	C	......	......	....	1		Copper disc (pressure gauge) bruised.
	C	......	......	....	2		
	C	......	......	....	1		Do.
	C	......	......	....	2		
	C	......	......	....	2		
	C	......	......	....	2		
From rear and left, 8°; 12 miles an hour.	C	......	......	....	....		
	C	......	......	....	....		
From front and right, 20°; 21 miles an hour.	C	......	3, 399	73. 3 right.	....	Fired down beach for ranges.	Good flight.
	C	......	3, 287	68. 1 right.	....		Fair flight.
	C	......	2, 890	25. 1 right.	....		Very irregular flight.
	C	......	3, 340	63. 3 right.	....		Fair flight.
	C	......	3, 401	72. 7 right.	....		Do.
	C	......	2, 620	58. 4 left.	....		Tumbled.
	C	......	Fell in sea.		....		Fluttering flight.
	C	......	Fell in sea.		....		Fair flight.
	C	......	2, 620	38. 7 left.	....		Tumbled.
	C	......	3, 354	58. 7 right.	....		Good flight.
	C	......	3, 254	234. 1 right.	....		Do.
	C	......	Fell in sea.		....		Tumbled.
	C	......	Fell in sea.		....		Good flight.
From right, 16 miles an hour.	......	......	......	....	....	Fired over water to try sabots of various thickness of lip.	Sabot lip $\frac{1}{30}$ inch thick. Slightly fluttering flight.
	......	......	......	....	....		Sabot lip $\frac{1}{20}$ inch thick. Good flight.
	......	......	......	....	....		Sabot lip $\frac{1}{10}$ inch thick. Good flight.

Record of firing with 12-inch muzzle-loading rifled mortar at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation. ° '	Pressure per square inch of bore (small Crusher). Lbs.	Instrumental velocity 115 feet from muzzle. Feet.	Recoil. Feet.	Wind—strength and direction.
P. M.—Barometer, 29.94; thermometer, 84; humidity, 69.	231	1886. July 22	Du Pont's hexagonal M. V. Density, 1.700; granulation, 72.	26	..	Eureka shell. Sabots carefully turned down to a uniform thickness of edge of lip (about 1/16 inch).	610	..	28	......	......	4.67	From rear and left, 15°; 12 miles an hour.
	232	July 22		26	..		610	..	28	......	......	4.67	
	233	July 22		26	..		610	..	28	......	......	4.67	
	234	July 22		26	..		610	..	28	......	......	4.67	
	235	July 22		26	..		610	..	28	......	......	4.67	
	236	July 22		26	..		610	..	28	......	......	4.67	
	237	July 22		26	..		610	..	28	......	......	4.67	
	238	July 22		26	..		610	..	28	......	......	4.67	
	239	July 22		26	..		610	..	28	......	......	4.67	
	240	July 22		26	..		610	..	28	......	......	4.67	
P. M.—Barometer, 29.790; thermometer, 80; humidity, 82.	241	July 27		26	..	Eureka.	610	..	60	......	......	1.33	From front and right, 60°; 8 miles an hour.
	242	July 27		26	..		610	..	60	......	......	1.33	
A. M.—Barometer, 29.860; thermometer, 75; humidity, 87.	243	July 28	Du Pont's sphero-hexagonal P. G. Density, 1.775; granulation, 100.	52	..		610	..	— 5	23,700	973	5.67	From front and left, 43°; 6 miles an hour.
	244	July 28		52	..		610	..	— 5	24,625	974	5.67	
	245	July 28		52	..		610	..	—10	25,000	974	5.67	
A. M.—Barometer, 30.045; thermometer, 69; humidity, 90.	246	Aug. 26	Du Pont's sphero-hexagonal O. V. No. 1. Density, 1.750; granulation, 100.	52	..	Eureka shell. D sabot.	610	..	28	......	......	5.58	From rear and right, 30°; 12 miles an hour.
	247	Aug. 26		52	..		610	..	28	......	......	5.58	
	248	Aug. 26		52	..		610	..	28	......	......	5.58	
P. M.—Barometer, 29.947; thermometer, 84; humidity, 57.	249	Aug. 26		52	..		610	..	28	......	......	5.58	
	250	Aug. 26		52	..		610	..	28	......	......	5.83	
	251	Aug. 26		52	..		610	..	28	......	......	5.83	
	252	Aug. 26		52	..		610	..	28	......	......	5.83	
	253	Aug. 26		52	..		610	..	28	......	......	5.83	
	254	Aug. 26		52	..		610	..	28	......	......	5.92	
	255	Aug. 26		52	..		610	..	28	......	......	5.92	
P. M.—Barometer, 30.176; thermometer, 68; humidity, 73.	256	Oct. 7		52	..	Eureka shell (new). D sabot.	610	..	60	27,600	......	3.25	From front and left 38°; 16 miles an hour.
	257	Oct. 7		52	..		610	..	60	......	......	3.42	
	258	Oct. 7		52	..		610	..	60	26,950	......	3.42	
	259	Oct. 7		52	..		610	..	60	......	......	3.42	
	260	Oct. 7		52	..		610	..	60	......	......	3.42	
	261	Oct. 7		52	..		610	..	60	......	......	3.42	

***Hook, N. J., from July* 15, 1885, *to October* 16, 1886—Continued.**

Kind of sabot.	Time of flight.	Ranges.	Deflection to right.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
	Secs.	*Yds.*	*Yds.*		
....	19½	3,532	79.2	Fired down beach for ranges.	Fair, but slightly fluttering, flight.
....	19½	3,471	75.8		Do.
....	19⅝	3,492	77		Fair, with more flutter.
....	19½	3,497	74.8		Fair, but slightly irregular at start.
....	19½	3,493	78.4		Slightly irregular, with marked flutter.
....	19½	3,505	77.1		Slightly irregular at start; fluttering throughout.
....	Lost.	3,498	76.2		Slightly fluttering. Fair flights.
....	19½	3,472	75.5		Do.
....	19⅝	3,476	74.9		Do.
....	19⅝	3,460	74.8		Do.
D	35	......	......	Fired down beach.	Good flight.
D	35	......	......		Do.
C	......	......	......	Fired into sand butt to try powder.	
C	......	......	......		
C	......	......	......		
....	28½	7,001	8	Fired to sea for range.	Fluttering flight.
....	Lost.	7,136	44		Fair flight.
....	28	7,190	35		Good flight.
....	28	7,204	20		Slightly fluttering flight.
....	28¼	7,254	31		Good flight.
....	28½	7,146	24		Do.
....	28	7,101	30		Do.
....	28¼	7,168	23		Do.
....	28¼	7,148	32		Do.
....	28½	7,072	40		Do.
....	50¾	6,244	580	Fired to sea for range.	Do.
....	50¾	6,648	540		Do.
....	50¾	6,992	499		Do.
....	50¼	6,344	524		Do.
....	50	6,476	512		Do.
....	50	6,316	538		Do.

Record of firing with 12-inch muzzle-loading rifled mortar at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (small Crusher).	Instrumental velocity.	Recoil.	Wind—strength and direction.
		1886.							° '	Lbs.	Feet.	Feet.	
P. M.—Barometer, 30.176; thermometer, 68; humidity, 73.	262	Oct. 7	Du Pont's sphero-hexagonal O. V. No. 1. Density, 1.750; granulation, 100.	52	..	Eureka shell (new). D sabot.	610	..	60	......	......	3.42	From front and left, 38°; 16 miles an hour.
	263	Oct. 7		52	..		610	..	60	......	......	3.42	
	264	Oct. 7		52	..		610	..	60	......	......	3.42	
A. M.—Barometer, 30.300; thermometer, 52; humidity, 81.	265	Oct. 8		52	..	Eureka shell (new). A sabot.	610	..	—10	......	......	5.58	From front and left, 87°; 7 miles an hour.
	266	Oct. 8		52	..		610	..	—10	26,700	......	5.58	
	267	Oct. 8		52	..		610	..	—10	......	......	5.58	
	268	Oct. 8		52	..		610	..	—10	26,200	......	5.58	
	269	Oct. 8		52	..		610	..	—10	......	......	5.58	
	270	Oct. 8		52	..		610	..	—10	......	......	5.58	
P. M.—Barometer, 30.221; thermometer, 65; humidity, 78.	271	Oct. 8		52	..		610	..	—10	......	......	5.58	
	272	Oct. 8		52	..		610	..	—10	......	......	5.58	
	273	Oct. 8		52	..		610	..	—10	......	......	5.62	
	274	Oct. 8		52	..		610	..	—10	......	......	5.58	
										Rodman.			
	275	Oct. 8	Du Pont's hexagonal M. V. Density, 1.700; granulation, 72.	26	..	Eureka shell (old). D sabot.	610	..	60	......	......	1.67	From front and left, 25½°; 7 miles an hour.
	276	Oct. 8		26	..		610	..	60	9,100	......	1.67	
	277	Oct. 8		26	..		610	..	60	......	......	1.58	
	278	Oct. 8		26	..		610	..	60	9,500	......	1.58	
	279	Oct. 8		26	..		610	..	60	......	......	1.58	
	280	Oct. 8		26	..		610	..	60	......	......	1.58	
	281	Oct. 8		26	..		610	..	60	......	......	1.33	
	282	Oct. 8		26	..		610	..	60	......	......	1.33	
	283	Oct. 8		26	..		610	..	60	......	......	1.42	
	284	Oct. 8		26	..		610	..	60	......	......	1.42	
A. M.—Barometer, 30.185; thermometer, 51.3; humidity, 73.	285	Oct. 9	Du Pont's sphero-hexagonal O. V. No. 1. Density, 1.750; granulation, 100.	52	..	Eureka shell (new). A sabot.	610	..	—10	......	......	5.58	From rear and right, 87°; 13 miles an hour.
	286	Oct. 9		52	..		610	..	—10	......	......	5.58	
	287	Oct. 9		52	..		610	..	—10	......	......	5.58	
	288	Oct. 9		52	..		610	..	—10	......	......	5.67	
	289	Oct. 9		52	..		610	..	—10	......	......	5.67	
	290	Oct. 9		52	..		610	..	—10	......	......	5.67	
	291	Oct. 9		52	..		610	..	—10	......	......	5.67	
	292	Oct. 9		52	..		610	..	—10	......	......	5.67	
	293	Oct. 9		52	..		610	..	—10	......	......	5.67	
	294	Oct. 9		52	..		610	..	—10	......	......	5.67	
	295	Oct. 9		52	..		610	..	—12	......	......	5.75	

Hook, N. J., from July 15, 1885, *to October* 16, 1886—Continued.

Time of flight.	Ranges.	Deflection to right.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Secs.	*Yds.*	*Yds.*	
$50\frac{1}{2}$	6,218	481	Fired to sea for range. Good flight.
$51\frac{1}{2}$	6,520	496	Do.
Lost.	6,600	501	Do.
......	......	......	Fired into sand butt for endurance test.
......	......	......	
......	......	......	
......	......	......	
......	......	......	
......	......	......	
......	......	......	
......	......	......	
......	......	......	
......	......	......	
$35\frac{1}{2}$	8,366	231	Fired down beach for accuracy. The ranges and deflections for these ten rounds were determined from the craters made by the shells in the sand. Only eight could be found. The order in which the shots were fired could not be determined. Good flight.
Lost.	8,329	248	Do.
$35\frac{1}{2}$	8,277	236	Do.
$85\frac{1}{2}$	3,267	237	Do.
$35\frac{1}{2}$	8,258	241	Do.
$35\frac{1}{2}$	3,217	249	Do.
36	8,208	235	Do.
$35\frac{1}{2}$	8,155	208	Do.
36	....	......	Do.
$35\frac{1}{2}$	......	......	Do.
......	......	......	Fired into sand butt for endurance test.
......	......	......	
......	......	......	
......	......	......	
......	......	......	
......	......	......	
......	......	......	
......	......	......	
......	......	......	
......	......	......	
......	......	......	

Record of firing with 12-inch muzzle-loading rifled mortar at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure, per square inch of bore (Rodman).	Instrumental velocity.	Recoil.	Wind—strength and direction.
		1886.							° ′	*Lbs.*	*Feet.*	*Feet.*	
A. M.—Barometer, 30.185; thermometer, 51.3; humidity, 72.	296	Oct. 9	Du Pont's sphero-hexagonal O. V. No. 1. Density, 1.750; granulation, 100.	52	..	Eureka shell (new). A sabot.	610	..	—12	......	......	5.71	From rear and right, 87°; 13 miles an hour.
	297	Oct. 9		52	..		610	..	—12	......	......	5.75	
	298	Oct. 9		52	..		610	..	—12	......	......	5.75	
	299	Oct. 9		52	..		610	..	—12	......	......	5.75	
	300	Oct. 9		52	..	Eureka shell. Old. D sabot	610	..	—12	......	......	5.75	
	301	Oct. 9		52	..	New. D sabot	610	..	—12	......	......	5.75	
	302	Oct. 9		52	..	New. A sabot	610	..	—12	......	......	5.75	
	303	Oct. 9		52	..	Old. A sabot	610	..	—12	......	......	5.75	
	304	Oct. 9		52	..	Old. A sabot	610	..	—12	......	......	5.75	
P. M.	305	Oct. 14		52	..	(Old.) Eureka shell. A sabot.	610	..	—12	......	......	5.83	From front and left, 43°; 20 miles an hour.
	306	Oct. 14		52	..		610	..	—12	......	......	5.83	
	307	Oct. 14		52	..		610	..	—12	......	......	5.75	
	308	Oct. 14		52	..		610	..	—12	......	......	5.75	
	309	Oct. 14		52	..		610	..	—12	......	......	5.75	
	310	Oct. 14		52	..		610	..	—12	......	......	5.75	
	311	Oct. 14		52	..		610	..	—12	......	......	5.75	
	312	Oct. 14		52	..		610	..	—12	......	......	5.75	
	313	Oct. 14		52	..		610	..	—12	......	......	5.71	
	314	Oct. 14		52	..		610	..	—12	......	......	5.71	
	315	Oct. 14		52	..		610	..	—12	......	......	5.67	
	316	Oct. 14		52	..		610	..	—12	......	......	5.75	
	317	Oct. 14		52	..		610	..	—12	......	......	5.75	
	318	Oct. 14		52	..		610	..	—12	......	......	5.75	
	319	Oct. 14		52	..		610	..	—12	......	......	5.75	
	320	Oct. 14		52	..		610	..	—12	......	......	5.75	
	321	Oct. 14		52	..		610	..	—12	......	......	5.75	
	322	Oct. 14		52	..		610	..	—12	......	......	5.75	
	323	Oct. 14		52	..		610	..	—12	......	......	5.75	
	324	Oct. 14		52	..		610	..	—12	......	......	5.75	
	325	Oct. 14		52	..		610	..	—12	......	......	5.75	
	326	Oct. 14		52	..		610	..	—12	......	......	5.75	
	327	Oct. 14		52	..		610	..	—12	......	......	5.75	

Hook, N. J., from July 15, 1885, *to October* 16, 1886—Continued.

	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Fired into sand butt for endurance test.	Two bolts holding step of worm for eccentric wheel on left-hand side of top carriage broken off, and one bolt holding corresponding step on right-hand side broken off.
	Before firing round 805 new bolts were put in to replace those broken holding step of worm for eccentric wheels of top carriage.

Record of firing with 12-inch muzzle-loading rifled mortar at Sandy

	No. of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (small Crusher).	Instrumental velocity.	Recoil.	Wind—strength and direction.
		1886.							° ′	*Lbs.*	*Feet.*	*Feet.*	
A. M.	328	Oct. 15	Du Pont's sphero-hexagonal O. V. No. 1. Density, 1.750; granulation, 100.	52	..	(Old.) Eureka steel. A sabot.	610	..	— 8	......	......	5.75	From rear and left, 3°; 28 miles an hour.
	329	Oct. 15		52	..		610	..	— 8	......	......	5.75	
	330	Oct. 15		52	..		610	..	— 8	......	......	5.75	
	331	Oct. 15		52	..		610	..	— 8	......	......	5.75	
	332	Oct. 15		52	..		610	..	— 8	......	......	5.75	
	333	Oct. 15		52	..		610	..	—12	......	......	5.83	
	334	Oct. 15		52	..	(New.) Eureka shell. A sabot.	610	..	—15	......	......	5.75	
	335	Oct. 15		52	..		610	..	—15	......	......	5.75	
	336	Oct. 15		52	..		610	..	—15	......	......	5.79	
	337	Oct. 15		52	..		610	..	—15	......	......	5.75	
	338	Oct. 15		52	..		610	..	—15	......	......	5.83	
	339	Oct. 15	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..		610	..	— 8	26,025	......	5.75	
	340	Oct. 15		48	..		610	..	—15	......	......	5.71	
	341	Oct. 15		48	..		610	..	—17	26,675	......	5.71	
	342	Oct. 15		48	..		610	..	—20	......	......	5.71	
	343	Oct. 15		48	..		610	..	— 8	......	......	5.71	
	344	Oct. 15		48	..		610	..	—15	......	......	5.71	
	345	Oct. 15		48	..		610	..	—15	......	......	5.71	
	346	Oct. 15		48	..		610	..	— 8	......	......	5.75	
	347	Oct. 15		48	..		610	..	— 8	......	......	5.75	
	348	Oct. 15		48	..		610	..	—20	......	......	5.71	
	349	Oct. 15		48	..		610	..	—20	......	......	5.71	
	350	Oct. 15		48	..		610	..	— 8	......	......	5.71	
	351	Oct. 15		48	..		610	..	— 8	......	......	5.71	
	352	Oct. 15		48	..		610	..	0	......	......	5.67	From rear and right, 43°; 30 miles an hour.
	353	Oct. 15		48	..		610	..	0	......	......	5.67	
	354	Oct. 15		48	..		610	..	—20	......	......	5.67	
	355	Oct. 15		48	..		610	..	—20	......	......	5.67	
	356	Oct. 15		48	..		610	..	—20	......	......	5.67	
	357	Oct. 15		48	..		610	..	—28	......	......	5.75	
	358	Oct. 15		48	..		610	..	—20	......	......	5.75	
	359	Oct. 15		48	..		610	..	—15	......	......	5.71	
	360	Oct. 15		48	..		610	..	—15	......	......	5.75	
	361	Oct. 15		48	..		610	..	—15	......	......	5.75	
	362	Oct. 15		48	..		610	..	—15	......	......	5.75	

Hook, N. J., from July 15, 1885, to October 16, 1886—Continued.

	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Fired into sand butt for endurance test.	Ten rounds (332 to 341, inclusive) fired in 79 minutes.
	Ten rounds (342 to 351, inclusive) fired in 87 minutes.
	One bolt, holding hanger or worm on right eccentric wheel of top carriage, broken off by shock of discharge.

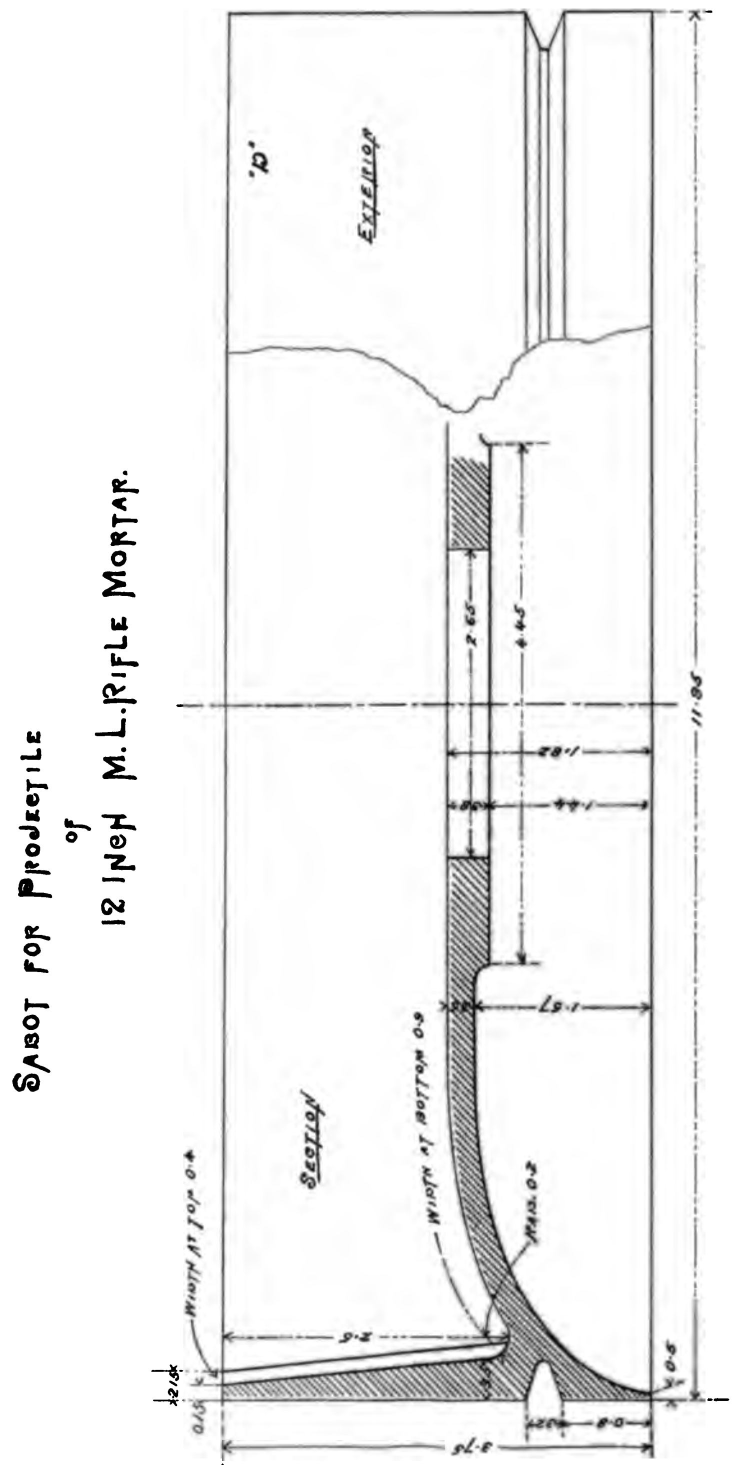
Record of firing with 12-inch muzzle-loading rifled mortar at Sandy

	No. of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure per square inch of bore (small Crusher).	Instrumental velocity.	Recoil.	Wind—strength and direction.
		1886.							° ′	*Lbs.*	*Feet.*	*Feet.*	
P. M.	363	Oct. 15	Du Pont's hexagonal M. W. Density, 1.725; granulation, 72.	48	..	(New.) Eureka shell. A sabot.	610	..	—20	......	......	5.75	From rear and right, 43°; 30 miles an hour.
	364	Oct. 15		48	..		610	..	—20	......	......	5.75	
	365	Oct. 15		48	.		610	..	—20	......	......	5.75	
	366	Oct. 15		48	..		610	..	—20	......	......	5.71	
	367	Oct. 15		48	..		610	..	—20	......	......	5.71	
	368	Oct. 15		48	..		610	..	—20	......	......	5.75	
	369	Oct. 15		48	..		610	..	—20	......	......	5.79	
	370	Oct. 15		48	..		610	..	—20	......	......	5.75	
	371	Oct. 15		48	..		610	..	—20	......	......	5.75	
	372	Oct. 15		48	..		610	..	—20	......	......	5.75	
	373	Oct. 15		48	..		610	..	—20	......	......	5.71	
	374	Oct. 15		48	..		610	..	—20	......	......	5.71	
	375	Oct. 16		48	..		610	..	—20	......	......	5.67	From rear and right, 43°; 40 miles an hour.
	376	Oct. 16		48	..		610	..	—20	......	......	5.75	
	377	Oct. 16		48	..		610	..	—20	......	......	5.75	
	378	Oct. 16		48	..		610	..	—20	......	......	5.75	
	379	Oct. 16		48	..		610	..	—20	......	......	5.75	
	380	Oct. 16		48	..		610	..	—20	......	......	5.83	
	381	Oct. 16		48	..		610	..	—20	......	......	5.83	

Hook, N. J., from July 15, 1885, *to October* 16, 1886—Continued.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
Fired into sand butt for endurance test.

PLATE I.


SABOT FOR PROJECTILE
of
12 INCH M.L. RIFLE MORTAR.
'D'
EXTERIOR
SECTION
WIDTH AT TOP 0.4
WIDTH AT BOTTOM 0.9
RAD. 0.2
11.95
4.45
2.65
1.82
1.44
1.67
2.6
3.75
0.8
0.5

APPENDIX 12.

PROGRESS REPORT ON TRIAL OF POWLETT PNEUMATIC GUN-CARRIAGE BY THE ORDNANCE BOARD.

(1 plate.)

On September 27, 1884, the Chief of Ordnance referred to the Ordnance Board for consideration and report a pamphlet containing a description, without details, of a pneumatic gun carriage, and directed the Board to await the arrival of the inventor of the gun-carriage, or some representative of the Powlett Pneumatic Gun-Carriage Company, before considering the matter.

After an interview with the representative of the company, and the receipt of an estimate for the cost of altering a 15-inch gun carriage, the Board, on October 24, 1884, recommended that the Pneumatic Gun-Carriage Company be permitted to apply their device to a 15-inch-gun carriage at Sandy Hook, with the understanding that if the system was successful the company should be paid for certain parts estimated for and applied to the carriage.

A letter from the company, dated April 20, 1885, referred to a clause in the fortification bill, then lately passed, authorizing the building of experimental gun-carriages, and submitted a drawing and estimate for a new carriage. The Board having been asked to express an opinion as to the amount of the estimate, reported that it considered the price a low one.

On May 21, 1885, a contract was made with the company to furnish "one Powlett Pneumatic Gun-carriage complete, with recoil-check, boiler and furnace, and all the machinery, appliances, and accessories necessary for its complete working and maneuvering for a 12-inch breech-loading rifle." It was required that the carriage should be subjected to five rounds with service charges, and work to the satisfaction of the Chief of Ordnance.

Subsequently the carriage was received, and on November 14, 1885, the Chief of Ordnance directed that the 12-inch breech-loading rifle, cast iron, should be mounted and fired from it.

The carriage (see plate) has been modified in several details since it was originally furnished. In general, it consists of a top carriage and chassis. The top carriage is provided with toothed arcs, connected to the gun in the usual manner, and has a pneumatic cylinder under each trunnion, with valves so arranged as to operate a rack and pinion, by which elevation and depression may be given. A friction-clutch clamps the arcs when the desired elevation is obtained. The chassis has two running cylinders (so termed by the inventor), placed at the rear and

connected by suitable branches with a supply-pipe leading to the air-compressing apparatus. A cock placed in the pipe permits the air to pass to the front or to the rear ends of the cylinders. The rear heads of the running cylinders contain axial perforations, to which valves are fitted. These valves are closed by air pressure admitted from the supply-pipe, and are operated by a lever and connecting-rod. The compressed air is admitted or cut off according as the lever is to the front or to the rear. At the bottom of each running cylinder, and near the rear, is a check-valve, which freely admits air from the supply-pipe, but is closed when the pressure from the cylinder exceeds that from the compressing apparatus. Similar check-valves are placed at the front in the vertical branches of the supply-pipes. The object of these check-valves is to relieve the supply-pipe and its connections from severe pressures.

The gun being in battery, if the pressure on the rear valves be relieved by moving their lever to the rear, and if compressed air be admitted to the front of the running cylinders, two pistons are forced back and the top carriage, with which they are connected, is moved from battery. The air passing from the rear of the cylinders as the pistons travel backwards presents no resistance to the action of the compressed air in front.

When it is desired to run the gun to battery, pressure is applied to the rear valves by moving their lever forward, and the compressed air now admitted to the rear of the cylinders forces the gun to the front. The air escapes from the front of the cylinders through waste-cocks, which are placed in the front vertical branches of the supply-pipes, between the cylinders and the check-valves previously mentioned. These cocks are operated by an independent lever.

When the gun is to be fired the waste-cocks are closed, pressure is applied to the valves in the rear ends of the cylinders, and compressed air having a suitable degree of tension is admitted to the rear of the cylinders, after which the cock in the supply-pipe is closed. A slide on the left cheek of the carriage, parallel and near to the shoe-plate, carries a projecting piece which can be given any desirable adjustment. As the gun recoils the projecting piece strikes the lever, which moves backward and opens the rear valves with which it is connected, thus relieving the pressure which otherwise would be so great as to cause the gun to run forward violently after recoil and injure the carriage. This occurred when the gun was first fired, and it was found essential not only to relieve the pressure behind, but that it would be necessary to admit compressed air to the front.

The chassis is traversed by a pair of oscillating cylinders, which the inventor states in his pamphlet "are placed at such an angle that there is no center of axis of motion."

When the carriage was first received the engines worked directly on a crank-shaft to which a gear wheel was keyed, its teeth intermeshing with those of a circular arc fastened to and concentric with one of the rear traverse wheels. The engines were operated by compressed air and governed by a lever, which being attached to valves moved them in such a way as to cause the gearing to rotate to the right or left.

A necessary appendage to the carriage is air-compressing machinery, but as the company does not base its claim on any special device for this purpose, it is not necessary to describe the engines, &c., used in this case.

The preliminary trial of this carriage is detailed in the following letter to the Chief of Ordnance, dated December 24, 1885:

I have the honor to report that the test of the pneumatic gun-carriage upon which the 12-inch cast-iron rifle had been mounted, was commenced yesterday before the Ordnance Board. The pressure of air in receiver having been raised to 150 pounds, connection was made with traversing apparatus by one man working a lever, when the carriage was rapidly and easily traversed to the right and left. The elevating apparatus was next tried, one man making the connection; the gun was elevated and depressed with great ease. Although the connections were easily made and motion rapidly communicated, it was found to be a difficult matter to lay the gun exactly on an object by breaking the connections, and it is thought for these small motions, necessary in accurately and rapidly pointing the gun, additional devices will have to be provided.

The gun was then loaded with 100 pounds of brown prismatic powder and a 700-pound shot and fired, the pressure of air in cylinders being about 160 pounds. The recoil was readily taken up in a distance of 19 inches, but the counter-recoil threw the gun into battery with violence. Another round was fired, everything being the same as before except that the powder charge was increased 50 pounds and the air pressure in cylinders was reduced to about 125 pounds. The recoil was 2 feet 8 inches and the counter-recoil more violent. For the third round the powder charge was further increased 50 pounds and the air pressure was reduced to 45 pounds. This recoil was 5 feet 8 inches, and the counter-recoil was so violent that the gun was thrown into battery with such force as to raise the rear end of the carriage, causing the guide-hooks to lift up and bend the top plate of chassis rail, breaking many of the bolts that held this plate to the rails. Firing will now have to be suspended until repairs are made, and to enable the company to apply some device to release the compressed air more promptly after the gun has recoiled. It will take about one week to complete these arrangements. * * *

The repairs required were made by the company, and the cock in the supply-pipe was connected with a system of levers so arranged that after the compressed air necessary to check recoil has been admitted to the rear the carriage in running back would turn the cock so far as to admit the air to the front of the cylinders before counter-recoil took place. With this object in view, the main lever of the system operating the cock was carried up so far that its upper end projected above the top of the chassis rail. In this position it encountered a stop attached to the slide near the shoe-plate of the top carriage, immediately after recoil began. The lever was thus carried backward until the cock was revolved far enough to admit the compressed air to the front of the working cylinders. This prevented the violent forward motion of the gun which had previously seriously injured the chassis.

After these changes had been effected the Board tried the carriage again, and on January 25, 1886, forwarded the following letter:

I have the honor to report that the test of the pneumatic gun-carriage has been completed as to the five rounds with 265 pounds of prismatic powder and 800-pound shot before it could be accepted and paid for under the contract, and that it has withstood this test satisfactorily. The Board before going on with the test of endurance of this carriage desires to call attention to the points made in its report of December 24, 1885, in regard to the difficulty of laying the gun quickly on an object and the necessity of additional devices to accomplish this, and would suggest that the Pneumatic Gun-Carriage Company be called upon to supply them. Without the changes indicated accurate laying of the gun is impossible and the carriage would be useless.

With regard to the use of compressed air for checking the recoil the Board sees no advantage over the use of the hydraulic cylinder heretofore used for this purpose, and it is besides much more expensive and complicated. It would, therefore, recommend that the hydraulic cylinders be substituted for this arrangement. * * *

The Chief of Ordnance, on February 2, 1886, returned the letter with an indorsement stating that the company within a brief period of time would supply the small details necessary to enable the carriage to be quickly laid in traversing and pointing. The indorsement further stated that the use of compressed air for checking recoil was an important element in the invention, and must be thoroughly tried with

the other parts until a conclusion on the merits of the whole was reached. The trial of the carriage, as to its merits and efficiency for service, was to be commenced and proceeded with as rapidly as possible.

Some of the devices required for operating the carriage more successfully were—

(1) A set of eccentric wheels for the rear of the top carriage to facilitate running out of battery.

(2) A worm, with the worm-gear and pinions, for traversing the chassis, as the action of the engines could be more readily controlled by means of the small motions incident to the use of worm-gearing. When a more direct connection was made, as in the carriage at first furnished, it was found very difficult to bring the chassis to rest when endeavoring to aim at a target.

(3) A device for accurately elevating and depressing the gun which allowed a counter-pressure to be applied in the cylinders placed directly under the trunnions. It was hoped by this means to be able to check the rotation of the gun about the axis of the trunnions more readily.

In April, 1886, a contract was entered into with the company for supplying these devices. When the work upon them had been completed, a trial was made in the presence of representatives of the company, and was reported upon July 20, 1886, as follows:

The Powlett pneumatic gun-carriage was, on July 16, 1886, tried in the presence of the Ordnance Board for the purpose of testing—

One set of wrought-iron eccentric wheels for accelerating the running out of battery.

One worm of wrought-iron, one bronze worm-gear, with accompanying pinion and traverse wheel, for accurately traversing the carriage.

One device for accurately elevating and depressing the gun.

These devices were contracted for April 2, 1886, and the contract has been extended to July 30, 1886.

At the trial on July 16 it was found that the inside guides are so short that the eccentric wheels cannot be thrown entirely into gear, and the front wheels of the top carriage are not circular, so that they move on the chassis rail sometimes by rotary friction and sometimes by sliding friction. Oiling holes should be provided for the journals of the front and rear wheels in order to insure their working. These defects should be remedied before the acceptance of the devices.

The devices for accurately traversing the carriage permit the gun to be laid upon any desired point readily and accurately.

The device for accurately elevating and depressing the gun was tried by changing the elevations and noting the times required, as follows:

From 0° to —5° in 22.75 seconds.
From —5° to 0° in 49 seconds.
From 0° to + 5° in 13.75 seconds.
From + 5 to 0° in 13.50 seconds.

A second trial gave the following results:

From 0° to — 5° in 14.5 seconds.
From — 5° to 0° in 29.75 seconds.
From 0° to + 5° in 24.75 seconds.
From + 5° to 0° in 19 seconds.

With this device the gun was elevated and depressed accurately by a skilled mechanic. It is thought that it would be difficult in service to obtain men capable of operating it.

Subsequently oiling holes were cut and the front truck-wheels were turned true at the expense of the company. With reference to the eccentric axles the company stated "that it was not their intention to throw the rear truck-wheels entirely into gear, as the only object of those wheels was to lift the top carriage off the slides, &c."

The carriage has not been changed further, and the Board desires to report upon it as finally submitted by the company.

The opinion of the Board is that the gun carriage can be accurately and quickly traversed by means of the worm-gearing. It can be laid in any desired line rapidly enough, it is thought, for the purposes of the land service.

The gun can be elevated and depressed with accuracy, but the time required in which to do this is as long, if not longer, than when the same is accomplished by hand, and the slight motions needed when the desired angle is nearly attained call for extreme care, such as a man in the excitement of action would find it difficult to exercise.

The complicated arrangement of supply pipes, branches, and valves would, unless they can be greatly simplified, be enough of themselves to cause the rejection of the elevating device.

The apparatus for checking the recoil, with its valves, cocks, levers, and branches, is too complicated for use in the land service, and is at its best far inferior to the ordinary hydraulic buffer, which requires but little care in preparing it for use and no attention during use. The only object that can be conceived of for applying these running cylinders is that the carriage was to be used with a pneumatic loading apparatus which was supplied later and was considered a partial failure.

As the rear truck-wheels cannot be thrown entirely into gear it is necessary to determine by use of a rule that the height of throw of the rear end of the top carriage does not exceed three-fourths inches. Should it do so there is risk of tearing off the guides and of injuring the rail top of the chassis. This construction of the axle was due very probably to ignorance and should have been remedied.

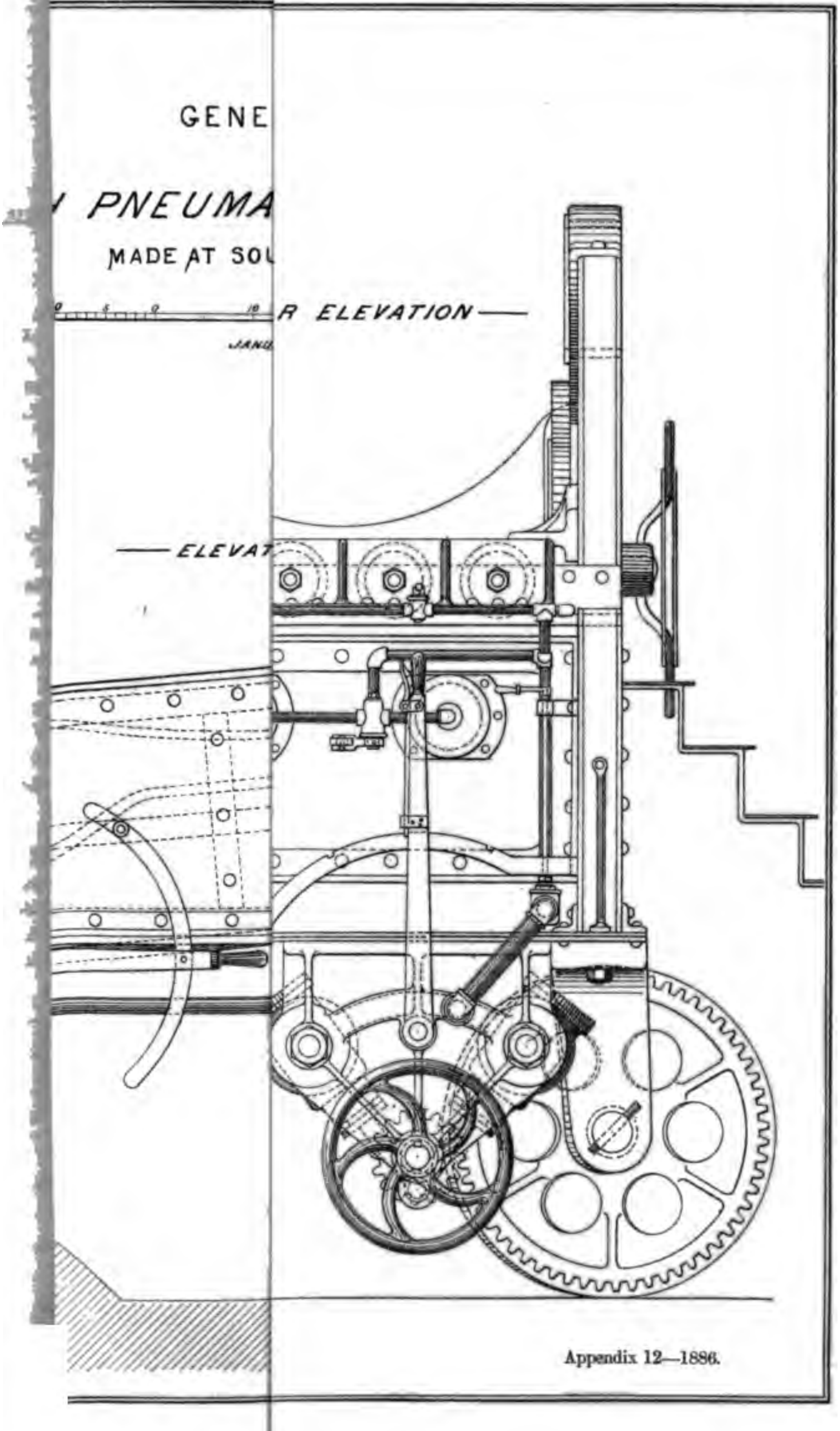
As to the general question of the use of compressed air for maneuvring sea-coast artillery it is not believed that it has been sufficiently tried as yet to warrant the expression of an opinion. It possesses certain advantages for our land service that makes its investigation in this country more important than it may be abroad.

The carriage exhibits many crudities naturally to be expected in a new design. It has been materially improved since it was first presented, and doubtless with the experience gained, the company can now simplify and strengthen its construction.

It is understood that the Navy is to try a new carriage furnished by the same company, and it is recommended that no further expenditure be made by the Ordnance Department until the naval carriage may have been tried.

The Board must, so far as its experience in the matter has gone, condemn the recoil and retraction system and the elevating apparatus, and, while recognizing merit in the traversing apparatus, desires, as before stated, to await the completion and trial of the carriage for the Navy before making any further recommendation on the subject.

J. MCALLISTER,
Colonel of Ordnance, President of the Board.
A. MORDECAI,
Lieut. Colonel of Ordnance.
CHARLES SHALER,
Captain of Ordnance.


GENE
PNEUMA
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APPENDIX 13.

REPORT ON EIGHT-INCH EXPERIMENTAL BANDED PROJECTILES, BY THE ORDNANCE BOARD.

(7 plates.)

An indorsement by order of the Chief of Ordnance dated October 14, 1885, directed the Board to test some 8-inch banded projectiles to be forwarded from Watertown Arsenal, and prescribed that the trials should be similar to those previously made with projectiles of the same form.

The trials previously made formed the subject of Ordnance Board report No. 8, of 1885, forwarded April 10th of the current year. The projectiles tried at that time were numbered 1, 2, 3, 4, and 5. The object of the present trial was to determine more fully the relative merits of Nos. 3, 4, and 5, which had been modified as will be explained.

The designation No. 3 indicated a projectile with a single cylindrical band one inch wide. In the original No. 3, the bottom of the band was 1″.5 from the base of the shot. Two lots of No. 3, ten in each lot, were used in this last trial. In the first lot the rear of the band was 1″.85 from the base, in the second lot 2″.1 from the base. In three of each lot the bands were of brass, said to contain 95 per cent. of copper, 5 per cent. spelter.

No. 4 designated a shot having two narrow cylindrical bands 0″.32 wide. The front band was originally placed with its rear 2″.6 from the base. Two lots of five each were used in this last trial. In the first lot the rear of the front band was moved 0″.25 forward, in the second lot 0″.5 forward.

No. 5 designated a shot having two broad cylindrical bands 0″.5 wide. The bottom of the front band was originally placed 2″.67 from the base. Two lots of five each were used in this last trial. In the first lot the position of the band was unchanged, in the second lot the front band was moved 0″.25 forward.

Table showing kind and number of shots with new and original positions of bands.

Designation.	Number supplied.	Kind of band.	Distance from base.		Difference.
			New.	Original.	
No. 3	7	Single copper	Rear of band 1″.85	Rear of band 1″.5	0″.35 forward.
	3	Single brass			
	7	Single copper	Rear of band 2″.1		0″.6 forward.
	3	Single brass			
No. 4	5	Double copper 0″.31 wide	Rear of front band 2″.85	Rear of front band 2″.6	0″.25 forward.
	5		Rear of front band 3″.10		0″.50 forward.
No. 5	5	Double copper 0″.5 wide	Rear of front band as in original	Rear of front band 2″.67	Unchanged.
	5		Rear of front band 2″.92		0″.25 forward.

The projectiles were cored shot twenty inches (20″) long. For a distance of seven and sixty-eight hundredth inches (7″.68) measured from the base the exterior surface was cylindrical and seven and ninety-three hundredth inches (7″.93) in diameter; thence for three-fourths of an inch (0″.75) it had the form of a conic frustum, the diameter of the anterior (the larger) base being seven and ninety-seven hundredth inches (7″.97); this frustum was surmounted by a cylinder two inches (2″) long. At a point ninety-five hundredth inches (0″.95) in front of the base of the cylinder is the origin of the ogival curve of the head. This curve is struck with a radius of two calibers—sixteen inches (16″.)

The gun was the 8-inch breech-loading chambered rifle No. 1 previously fired with similar projectiles.

The powder used before was E. V. M., but as none of that type remained on hand, E. V. F., having the same density, 1.750, and the same granulation, 72, was substituted. This powder when fired in thirty-five pound charges from the 8-inch muzzle-loading gun with the 180-pound projectile gave a mean pressure of 29,333 pounds, only about 1,000 pounds greater than did the E. V. M. powder. Fifty-pound charges were therefore used at first, but as the pressure increased until it reached 39,700 pounds, and as it was evident that with the No. 5 band the diminished air-space would cause the pressure to increase, it was directed that the remaining thirty-seven rounds should be fired with forty-five pound charges. As a result variable angles were used in firing the first lot of No. 3 projectiles.

It was desirable, if possible, to use the same charge and obtain as nearly as practicable the same velocities as before, but as it was not considered safe to exceed 35,000 pounds pressure in this gun, and as forty-five pound charges occasionally gave pressures exceeding 33,000, this charge was fixed upon.

As hexagonal powder which has been stored for several years gives results which sometimes vary with each barrel, twenty barrels of E. V. F. powder were intimately mixed before the trial. The pressures and velocities, as will be seen by the record, were very uniform for each series of projectiles.

The trial began October 28, 1885. One shot with a single brass band two and one-tenth inches (2″.1) from the base (round 83 of the accompanying record) was fired into the sand butt to ascertain if the grooves on the sabot were well defined. A mark was made with a cold-chisel on the band and on the shot, in order that if slipping occurred, it might be detected. All the other shot were fired through wire targets at a mile target, and velocity, pressure, and nature of flight, as well as accuracy, were noted in each case. The firing records herewith inclosed show the results, but they are tabulated with those obtained in the previous firing for the sake of comparison.

Table showing results obtained in firing original and modified 8-inch breech-loading projectiles.

Designation.	Kind of band.	Distance from base in inches.	No. of rounds.	No. of hits.	Angle of fire.	Velocities.			Mean deviations.		
						Maximum.	Minimum.	Mean.	Vertical.	Horizontal.	Absolute.
						Feet.	*Feet.*	*Feet.*	*Ft.*	*Ft.*	*Ft.*
Original No. 3.	Single copper ..	Rear of band, 1.5..	4	4	Variable.	1,510	1,494	1,503	2.67	2.37	3.53
Modified No. 3	Single copper ..	Rear of band, 1.85.	7	5	Variable.	1,480	1,469	1,475	5.28	1.80	5.61
Modified No. 3.	Single brass ...	Rear of band, 1.85.	3	3	2° 34′	1,481	1,467	1,473	3.33	2.33	4.06
Modified No. 3.	Single copper ..	Rear of band, 2.1..	7	7	2 34	1,483	1,477	1,480	1.12	1.12	1.58
Modified No. 3.	Single brass ...	Rear of band, 2.1..	2	0	2 34	1,476	1,470	1,473	No hits.		
Original No. 4	Double copper.	Rear of front band, 2.6.	4	4	2 25	1,528	1,517	1,524	1.71	1.71	2.45
Modified No. 4.	Double copper.	Rear of front band, 2.85.	5	5	2 35	1,490	1,481	1,487	3.90	1.92	4.35
Modified No. 4	Double copper.	Rear of front band, 3.1.	5	5	2 35	1,490	1,483	1,487	1.04	1.36	1.71
Original No. 5.	Double copper.	Rear of front band, 2.67.	4	4	2 25	1,510	1,507	1,509	2.25	0.78	2.35
2d series No. 5.	Double copper.	Same as above ...	5	5	2 35	1,484	1,475	1,479	2.00	1.04	2.25
Modified No. 5.	Double copper.	Rear of front band, 2.92.	5	5	2 35	1,490	1,479	1,483	1.44	1.33	1.96

As projectiles with single copper band 1.85 from the base were fired with variable charges and variable angles for reasons stated in this report, the results obtained with them do not furnish an adequate basis for comparison, and the experiment should, it is thought, be repeated. The projectiles with single brass bands 1.85 inches from the base gave greater lateral deviations (the only ones that under the circumstances can be compared) than the copper ones situated at the same distance and are considered inferior.

The best results were obtained with No. 3 projectiles having single copper band 2.1 inches from the base. The No. 3 projectiles with brass bands 2.1 inches from the base struck short. There seems to be no good explanation for this, as when recovered from the butt the brass bands had their grooves sharply defined and showed no evidence of shearing or slipping.

No. 4 modified with rear of front band 3.1 inches from the base and No. 5 modified with rear of front band 2.92 inches from the base gave better results than the others of the same designation, and as the table shows there is not very much difference between these and the No. 3 which gave the best results.

The gun was fired under the same angle with Nos. 3, 4, and 5, the center of impact is higher for 4 and 5 than for 3, but this is partly accounted for by the prevalence of a rear wind moving at the rate of 20 miles an hour with the former and a head wind of 11 to 12 miles an hour with the latter.

In conclusion the Board would state that it considers the projectiles designated as No. 3, with a single copper band placed 2.1 inches from the base, as the best, but recommends that a further trial be made with a projectile which is similar, but has its band placed 1.85 inches from the base.

Firing and target records and a table of enlargements are inclosed.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Table showing enlargements of bore and chamber of 8-inch breech-loading chambered rifle No. 1.

Inches from muzzle.	Original diameter of bore.	Enlargement of bore after— 5 rounds.	18 rounds.	62 rounds.	88 rounds.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
93½	7.985	0.017	0.032	0.072	0.076
93	7.986	.015	.030	.070	.073
92	7.987	.013	.027	.067	.069
91	7.988	.012	.024	.063	.066
90	7.989	.010	.021	.059	.060
89	7.990	.009	.019	.055	.056
88	7.992	.006	.017	.050	.050
87	7.995	.003	.014	.044	.045
86	7.996	.003	.012	.040	.043
85	7.998	.003	.010	.036	.040
84	7.999	.002	.009	.035	.038
83	7.999	.004	.009	.034	.037
82	8.001	.003	.007	.029	.030
81	8.001	.003	.008	.028	.029
80	8.001	.003	.008	.027	.029
78	8.002	.002	.006	.024	.026
76	8.001	.002	.006	.023	.025
74	8.001	.002	.005	.019	.024
72	8.001	.003	.005	.025	.029
70	8.000	.008	.012	.033	.033
68	8.000	.007	.012	.028	.028
66	8.001	.002	.008	.025	.026
64	8.001	.002	.005	.023	.025
62	8.001	.002	.005	.022	.024
60	8.001	.001	.004	.022	.023
58	8.001	.002	.004	.022	.023
56	8.001	.003	.008	.023	.023
54	8.001	.002	.005	.026	.024
52	8.001	.001	.005	.021	.022
50	8.001	.001	.005	.021	.022
48	8.001	.001	.004	.020	.021
46	8.001	.000	.004	.019	.021
44	8.001	.001	.009	.022	.021
42	8.001	.001	.010	.024	.021
40	8.001	.000	.009	.021	.019
38	8.000	.001	.006	.020	.020
36	8.000	.000	.005	.020	.020
34	8.000	.000	.004	.018	.019
32	8.000	.000	.004	.017	.019
30	8.000	.000	.004	.017	.019
28	8.000	.000	.004	.017	.018
26	8.000	.000	.004	.017	.018
24	8.000	.000	.004	.025	.024
22	8.000	.000	.004	.017	.020
20	8.000	.000	.004	.019	.020
18	8.000	.000	.004	.018	.019
16	8.000	.000	.004	.018	.018
14	8.000	.000	.004	.018	.019
12	8.000	.000	.005	.018	.019
10	8.000	.000	.005	.018	.018
8	8.000	.000	.005	.015	.017
6	8.000	.000	.005	.021	.023
4	8.000	.000	.005	.027	.027
2	8.001	−.001	.004	.025	.026
1	8.002	−.001	.003	.023	.026

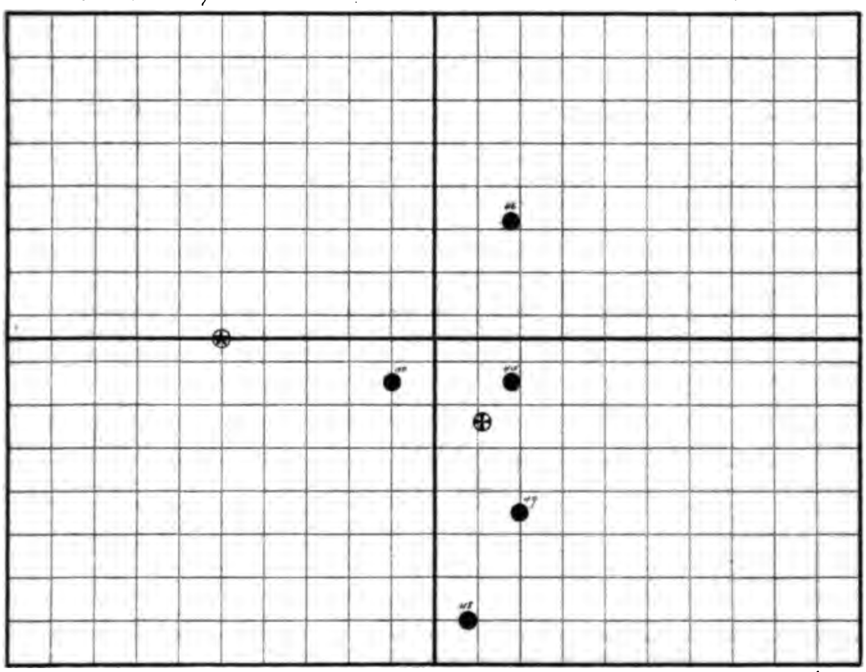
Inches from breech.	Original diameter of chamber.	Enlargement of chamber after— 5 rounds.	18 rounds.	62 rounds.	88 rounds.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
26	8.996	0.000	0.003	0.007	0.008
26½	9.000	.000	−.001	.003	.005
27	9.000	.000	.000	.003	.005
27½	9.000	.000	.000	.003	.005
28	9.000	.000	.000	.003	.005
28½	9.000	.000	−.001	.003	.004
29	9.000	.000	−.001	.003	.003
29½	8.999	.000	−.001	.003	.003
30	8.597	.000	.000	.000	.002
30½	8.996	.000	.001	−.002	.003
31	8.995	.000	.000	.000	.002
31½	8.995	.000	−.001	.000	.001
32	8.995	.000	−.001	.000	.001
32½	8.995	.000	−.001	.000	.001
33	8.995	.000	−.001	.000	.001
33½	8.995	.000	−.002	.000	.000
34	8.995	.000	−.003	.000	.000
34½	8.994	.000	−.002	.002	.001
35	8.094	.000	−.003	.002	.001
35½	8.994	.000	−.003	.002	.001
36	8.994	.000	−.002	.002	.001
36½	8.995	.000	−.003	.001	.000
37	8.995	.000	−.003	.002	.001
37½	8.996	.000	−.003	.002	.001
38	8.997	.000	−.002	.002	.001
38½	8.997	.000	−.002	.003	.002
39	8.998	.000	−.002	.003	.002
39½	8.998	.000	−.002	.004	.003
40	8.998	.000	.000	.005	.004
40½	8.998	.000	.000	.005	.004
41	8.999	.000	−.001	.003	.003
41½	8.999	.000	−.001	.003	.002
42	8.099	.000	−.002	.001	.001
42½	8.999	.000	−.002	.001	.001
43	8.997	.000	.000	.003	.003
43½	8.997	.000	−.001	.002	.001
44	8.995	.000	.000	.002	.002
44½	8.995	.000	−.001	.002	.002
45	8.994	.000	.000	.003	.003
45½	8.987	.000	.003	.008	.009

TARGET RECORD of [illegible]

October 28. 1885 AT SANDY HOOK. N. J.

No. 8 [illegible] Target [illegible] from Gun.

Number of shots fired, 7 . *Direct hits,* 5 . *Ricochet hits,* 1 . *Misses,* 1 .



● *Center of impact.*

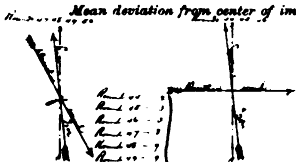
⊛ *Point aimed at.*

Mean vertical deviation from center of impact, 5.28.

Mean horizontal deviation from center of impact, 1.80.

Mean deviation from center of impact, 5.61.

Target 30 × 40



Wind [illegible] *miles per hour.*

H Ex1 pt2 v3 49 2

PLATE II.

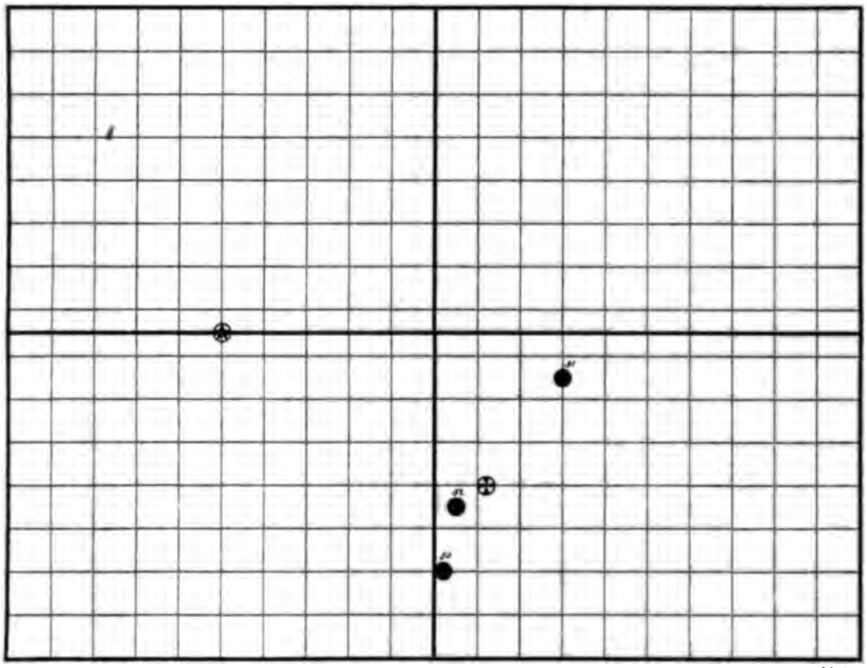
TARGET RECORD of 8-inch converted [illegible] Chambered [illegible],

October 28 1886 AT SANDY HOOK, N. J.

No. 3; brass band 1".85 front base

Target One mile *from Gun.*

Number of shots fired, 3 . *Direct hits,* 3 . *Ricochet hits,* 0 . *Misses,* 0



● *Center of impact.*

⊕ *Point aimed at.*

Target 30 × 40

Mean vertical deviation from center of impact, 3'.33

Mean horizontal deviation from center of impact, 2'.33

Mean deviation from center of impact, 4'.06

H Ex1 pt2 v3 49 2

Wind 11 *miles per hour.*

Appendix 13—1886.

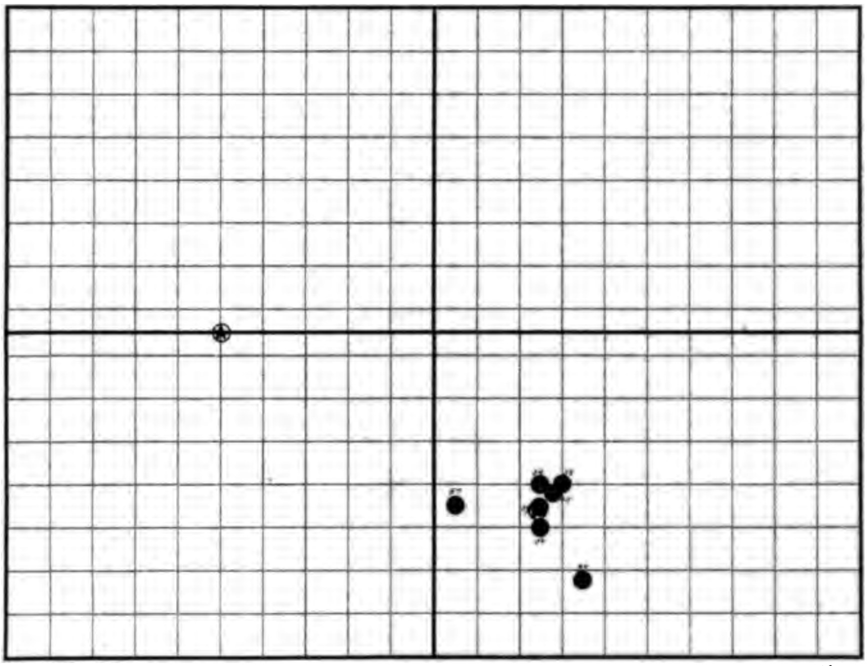
TARGET RECORD of 8 inch breech loading chambered rifle, No. 1

October 28. 1885 AT SANDY HOOK, N. J.

No. 3, copper band 2" from base

Target One mile from Gun.

Number of shots fired, 7 . *Direct hits,* 7 . *Ricochet hits,* 0 . *Misses,* 0 .



● *Center of impact.*

⊛ *Point aimed at.*

Mean vertical deviation from center of impact, 1'.12

Mean horizontal deviation from center of impact, 1'.12

Mean deviation from center of impact, 1'.58

Target 30 × 40

Wind [illegible] *miles per hour.*

H Ex1 pt2 v3 49 2

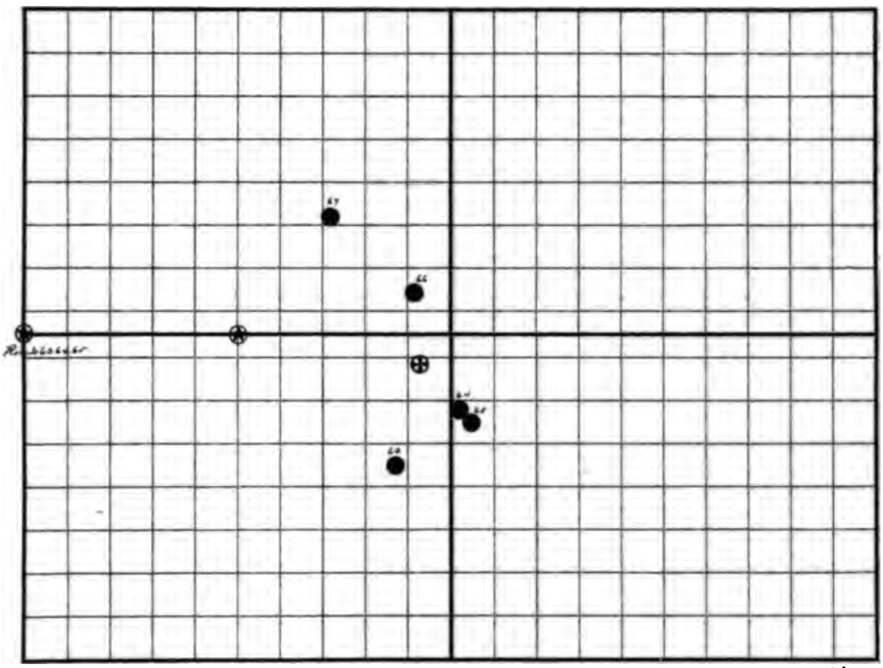
TARGET RECORD of [illegible] rifle No. 1

October 29 & 31. 1885 AT SANDY HOOK. N. J.

No. 4; [illegible]

Target One mile *from Gun.*

Number of shots fired, 5 . *Direct hits,* 5 . *Ricochet hits,* 0 . *Misses,* 0 .



Center of impact.

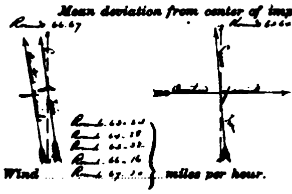
Point aimed at.

Mean vertical deviation from center of impact, 3'.90.

Mean horizontal deviation from center of impact, 1'.92.

Mean deviation from center of impact, 4'.35

Target 30 × 40.



Wind ... *miles per hour.*

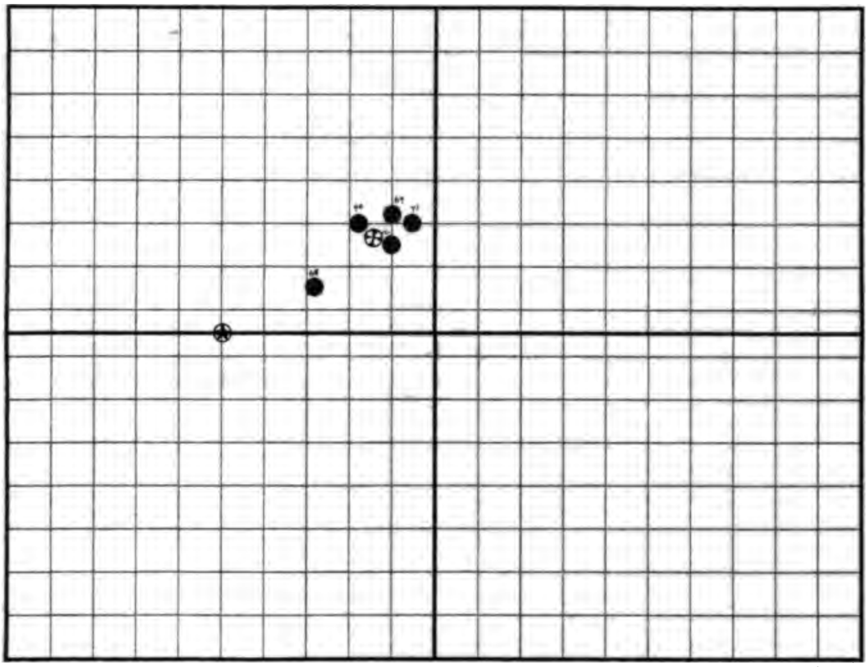
TARGET RECORD of [illegible] breech loading Chambered rifle No 1

October 31. 1885 AT SANDY HOOK. N. J.

No 4, front band 8.1 from base.

Target One mile from Gun.

Number of shots fired, 5 . *Direct hits,* 5 . *Ricochet hits,* 0 . *Misses,* 0



Center of impact.

Point aimed at.

Target 30 × 40.

Mean vertical deviation from center of impact, 1.04

Mean horizontal deviation from center of impact, 1.36

Mean deviation from center of impact, 1.71

H Ex1 pt2 v3 49 2

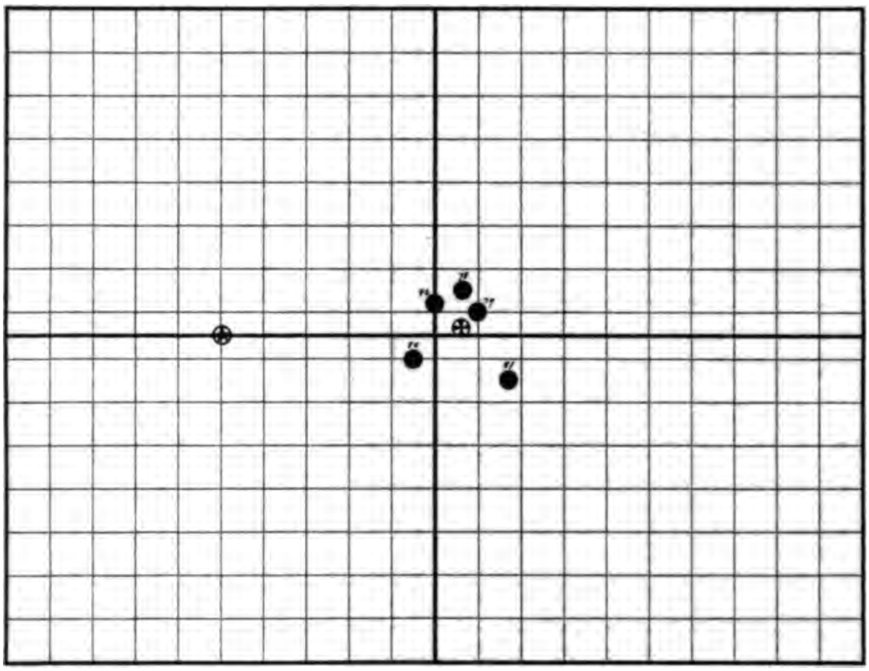
Wind 20 *miles per hour.*

PLATE VI.

TARGET RECORD of 8 inch breech loading Chambered rifle No 1

October 31. 1885 AT SANDY HOOK. N. J.
No 5; front band 2.92 from base.
Target One mile from Gun.

Number of shots fired, 5. *Direct hits,* 5. *Ricochet hits,* 0. *Misses,* 0.



● *Center of impact.*

⊕ *Point aimed at.*

Target 30 × 40.

Mean vertical deviation from center of impact, 1.'44.

Mean horizontal deviation from center of impact, 1.'33

Mean deviation from center of impact, 1.'96.

Wind 20 *miles per hour.*

APPENDIX 14.

DESIGN FOR 7-INCH SIEGE HOWITZER.

(2 plates.)

THE ORDNANCE BOARD, U. S. A., NEW YORK ARSENAL,
Governor's Island, N. Y. H., June 2, 1886.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.:

SIR: I have the honor to forward herewith a design for a siege-howitzer, the details of which have been worked up and made the subject of a report by Lieutenant Medcalfe. The report is herewith inclosed.

The Board assumed as bases for the investigation: (1) That weight of piece which could be transported with an army over ordinary roads and ponton bridges; (2) the mass of material being thus determined, that arrangement of the mass which would give the most powerful piece practicable, and one which would give to its projectile a range of 6,000 yards.

A weight of 3,750 pounds was adopted, and the various calculations made indicated that a 7-inch howitzer would best fulfill the conditions imposed.

As powerful a howitzer of the same caliber could be made with less material, but the quantity of motion of such a piece, when fired, would be so great that it might fairly be called impracticable.

With the same weight of metal, viz, 3,750 pounds, a larger and more powerful howitzer could be made, but for the same reason it would be impracticable. A certain amount of weight must be, and in foreign services is, allowed for such pieces. The foreign howitzer which most nearly corresponds to this piece is the Austrian 18^{cm} ($7''.09$) bronze steel howitzer. Its weight is 4,409 pounds.

Except the 42-pounder, there has heretofore been no gun of a 7-inch caliber in the United States land service, but there does not at present seem to be a necessity for arbitrarily adopting any particular caliber, and the basis of the most powerful mortar which can be conveniently carried over ponton bridges, a condition which governed in planning the 5-inch breech-loading siege-gun, appeared to be the proper one.

A sheet, giving dimensions of forgings required to make the howitzer, is forwarded. Detailed drawings of the breech mechanism will be commenced when the action of the Department on the general plan of the piece is made known to the Board.

For the Board.

Very respectfully, your obedient servant,

A. MORDECAI,
Lieutenant-Colonel of Ordnance, Senior Member Present.

[First indorsement.]

ORDNANCE OFFICE, *Washington, June* 8, 1886.

Respectfully returned to the Ordnance Board, U. S. A., with instructions to furnish this office with a form of advertisement and specifications for the steel forgings required for the howitzer. The form used for the 5-inch siege-gun is inclosed herewith for its guidance. By order of the Chief of Ordnance.

CHAS. S. SMITH,
Captain of Ordnance.

[Second indorsement.]

THE ORDNANCE BOARD, U. S. A.,
Governor's Island, N. Y. H., June 11, 1886.

Respectfully returned to the Chief of Ordnance, U. S. A.

The printed form of advertisement and specifications for the 5-inch siege-gun will, with the slight changes indicated in ink on the said form (which is returned), answer for the 7-inch steel howitzer.

For the Board.

A. MORDECAI,
Lieutenant-Colonel of Ordnance, Senior Member Present.

THE ORDNANCE BOARD, U. S. A., NEW YORK ARSENAL,
Governor's Island, N. Y. H., June 2, 1886.

The PRESIDENT OF THE ORDNANCE BOARD, U. S. A.,
Governor's Island:

SIR: I have the honor to submit the following calculations and drawings for a 7-inch siege-howitzer, prepared under the direction of the Ordnance Board.

A velocity of 955 feet at the muzzle is desired to give the necessary range, and the weight of the projectile carrying sufficient bursting charge has been previously determined to be 105 pounds. The weight of the gun is to be about 3,750 pounds.

The following data are therefore assumed:

Caliber=c=7 inches.
Weight of shell=p=105 pounds.
Initial velocity=v=960 feet.
Density of loading=Δ=0.85.
Maximum pressure=P_0=20,000 pounds.

With these data and formulas (85), p. 88, "*Recherches sur le chargement des bouches à feu,*" we can determine the weight of charge, length of bore, and kind of powder to be employed to obtain the desired conditions.

The results are given in the following table:

Modulus of the powder. x	Ratio of the weight of the projectile to the weight of the charge. $\frac{\omega}{p}$	Length of travel of shot in bore expressed in calibers. $\frac{u}{c}$	Weight of charge.	Logarithmic characteristic of suitable powder. $\log a$
			Pounds.	
1.1	0.0703	9.52	7.38	0.32724
1.0	0.0749	8.65	7.87	0.31689
0.9	0.0804	7.79	8.44	0.30545
0.8	0.0870	6.92	9.13	0.29262
0.7	0.0960	6.15	10.08	0.27650

Taking the case of $x=1.0$, we see that with a charge of about 8 pounds of suitable powder and a travel of the shot in the bore of 8.6 calibers, we should obtain the desired velocity with a pressure not exceeding 20,000 pounds.

A gun of this length would weigh but 2,240 pounds, and to utilize the metal needed to bring the weight up to 3,750 pounds, a greater length of bore can be assumed, and a gun calculated which will permit the use of a reduced charge when it is desired to obtain the required velocity of 955 feet; and also a maximum charge giving when needed a greater velocity.

As it was also desirable to have a surplus of weight over that absolutely required for strength, in order to reduce the shock on the carriage, a length of bore of about 12 calibers was assumed as giving a gun fulfilling both conditions.

Preliminary calculations lead to the assumption of the following data:

Caliber=7 inches.
Diameter of chamber=7.1 inches.
Length of chamber with De Bange gas-check=10.44 inches.
Volume of chamber, exclusive of volume occupied by gas-check= $\delta=306.84$ cubic inches.
Travel of shot in bore=u=76.25 inches.
Total length of bore=86.69 inches.

Formulas 84, p. 85, *Recherches sur le chargement des bouches à feu*, enable us to determine the charges and kinds of powder best suited to a gun of the above interior dimensions.

[Data: c=7 u=76.25; s=306.84 p=105 P_o=20,000 pounds.]

Modulus. x	Height of charge. ω	Density of loading. Δ	Initial velocity. V	Logarithmic characteristic of suitable powder. *log* α
	Pounds.		*Feet.*	
1.2	8.390	0.757	1,007	0.33145
1.1	8.818	0.796	1,027	0.31255
1.0	9.313	0.841	1,050	0.29185
0.9	9.893	0.893	1,076	0.26895

X=1.1 corresponds nearly to I. K. B. and L. X. powders. The characteristics of these powders have been deduced from firing them in the 3″.2 breech-loading field-gun, and were found to be:

For I. K. B., log $\alpha=0.31273$; log $\beta=0.14618$.
For L. X., log $\alpha=0.31562$; log $\beta=0.16297$.

The maximum charge will be determined by the density of loading that can be conveniently attained using the De Bange gas-check. Ten pounds gives a density of loading=0.9, and is therefore assumed as the maximum charge.

Using I. K. B. powder and calculating the velocity by Sarrau's formula for quick powders,

$$V=M\,\alpha\,\beta^{-\frac{1}{4}}\frac{\omega^{\frac{1}{2}}\Delta^{\frac{1}{4}}c^{\frac{1}{4}}u^{\frac{3}{8}}}{p^{\frac{1}{2}}}$$

log $M=2.84570$.

We find for $\omega=8$ pounds V=957.6 feet density of loading= $\Delta=0.722$;
for $\omega=10$ pounds V=1101.0 feet density of loading= $\Delta=0.902$.

L. X. B. powder gives higher pressures as well as higher velocities than any of the lots of L. X. or I. K. powders; the characteristics of that powder will therefore be used to determine the maximum pressure to be expected.

From firing the 3''.2 breech-loading steel rifle we have:

For L. X. B., log α=0.33940; log β=0.17243.

For calculating the pressure on the bottom of the bore we have the formula:

$$P_0=K_0\,\alpha^2\,\frac{\Delta\,\pi^{\frac{2}{3}}\,p^{\frac{2}{3}}}{c^2}$$

log K_0=4.25090.

We find for ω=8 pounds L. X. B.; P_0=19,080 pounds,

for ω=10 pounds L. X. B.; P_0=28,190 pounds, say 28,500.

The remaining calculations are made for the maximum charge.

To find the distance traveled by the projectile before the maximum pressure is obtained, Sarrau's formula 110, p. 133, Proceedings of U. S. Naval Institute, Vol. X, is used.

$$U=0.6\,\mu_0\left(1-\frac{\Delta}{\delta}\right)$$

U=distance traveled by projectile before maximum pessure is attained.

μ_0=*reduced length* of chamber or length of a cylinder having the volume of the chamber and a base having an area equal to that of a right section of the bore.

Δ=density of loading.

δ=real density of the powder.

For the gun considered we have, using 10 pounds of L. X. powder:

μ_0=7''.973, Δ=0.002, δ=1.704

U=2''.251.

To calculate the interior pressure at different points of the bore, it is assumed that Krupp's formula, given on page 139, *Revue d'Artillerie* November, 1883, represents the law of pressures after the projectile has passed the point of maximum pressure.

The formula is:

$$P=P_0\left(\frac{J_v}{J}\right)^{1.11}$$

P=pressure to be determined at any point.

P_0=maximum pressure=28,500 pounds=12.73 tons.

J_v=volume of bore in rear of right section through point; 2''.25 in in front of face of chamber=393.48 cubic inches.

J=volume of bore up to point at which the pressure=P.

To find the probable factor of effect of the gun, the work capable of being done by the charge is calculated from Table 1, Mackinlay's Text Book of Gunnery, and found to be 1,139.39 foot-tons.

For V=1,100 feet, W=105 pounds, we have $\frac{WV^2}{2g\times 2240}$=881.8 foot-tons.

The factor of effect is therefore $\frac{881.8}{1139.4}$=77.4 per cent.

This factor is used in calculating the effective work performed on the projectile, and the velocity attained by the latter at different points along the bore.

The results are given in the following table:

Distance from face of chamber.	Effective work performed on projectile.	Velocity.	Pressure in bore.
Inches.	*Foot-tons.*	*Feet.*	*Tons per square inch.*
2. 25	150. 39	454. 3	12. 73
4. 0	228. 71	560. 2	10. 69
7. 5	340. 38	683. 4	8. 04
11. 0	420. 37	759. 5	6. 41
10. 0	532. 28	854. 6	4. 52
25. 0	610. 90	915. 6	3. 47
33. 0	671. 21	959. 7	2. 80
46. 0	761. 03	1, 021. 9	2. 01
60. 0	834. 35	1, 070. 0	1. 55
*76. 25	881. 80	1, 100. 0	1. 23

* Muzzle

To obtain approximate thickness of walls over chamber the following formula is used (Mackinlay, p. 17):

$$p\,d\,f = 2\,m\,t_0 + 2\,n\,t_1.$$

f = factor of safety, assumed = 4.
d = diameter of chamber = 7''.1.
p = maximum pressure = 12.73 tons = 28,500 pounds.
t_0 = tenacity of tube = 80,000 pounds.
t_1 = tenacity of jacket = 90,000 pounds.
m = thickness of tube, assumed = 2''.
n = thickness of jacket.
Whence n = 2.73 and thickness of walls = $m + n$ = 4.72.

Starting with this thickness of wall over the seat of the projectile, the gun is proportioned as shown in the accompanying drawings, so as to bring up the weight to about 3,750 pounds, and distribute the metal symmetrically. The jacket is carried farther forward than absolute strength requires to increase the weight.

The center of gravity of the gun is 36''.71 from the breech. The axis of the trunnions is placed at 37''.3 from the breech to allow a preponderance of about 50 pounds at a point 18''.3 in rear of that axis, the position of the rear end of the elevating arc.

To complete the elastic resistances at different points and the shrinkage to be adopted for the jacket, the formulas given in construction note No. 35 are used.

The physical qualities of the metal are assumed as follows:

For tube $\begin{cases} \theta_0 = \rho_0 = 42{,}000 \text{ pounds.} \\ E_0 = 29{,}000{,}000 \text{ pounds.} \end{cases}$ For jacket $\begin{cases} \theta_1 = \rho = 52{,}000 \text{ pounds.} \\ E_1 = 29{,}000{,}000 \text{ pounds.} \end{cases}$

The limiting values of the elastic displacements of the metals are therefore

$$\text{For tube } \frac{\Delta R_0}{R_0} = \frac{d\,\Delta R_0}{d\,R_0} = \frac{\theta_0}{E_0} = 0.001448.$$

$$\text{For jacket } \frac{\Delta R_1}{R_1} = \frac{d\,\Delta R_1}{d\,R_1} = \frac{\theta_1}{E_1} = 0.001793.$$

The elastic strength of the gun has been determined at five points, viz: over chamber; $2\frac{1}{2}$ inches in front of chamber; at forward end of jacket; at commencement of chase; at the muzzle.

The data are—

$$(1)\begin{cases} R_0=3.55 \\ R_1=5.83 \\ R_2=8.25 \end{cases} (2)\begin{cases} R_0=3.50 \\ R_1=5.50 \\ R_2=8.25 \end{cases} (3)\begin{cases} R_0=3.50 \\ R_1=5.50 \\ R_2=7.50 \end{cases} (4)\begin{cases} R_0=3.50 \\ R_1=5.50 \end{cases} (5)\begin{cases} R_0=3.50 \\ R_1=5.00 \end{cases}$$

From formula (30″) we obtain—

(1) $P_0=34{,}824$ pounds$=15.546$ tons.
(2) $P_0=34{,}616$ pounds$=15.454$ tons.
(3) $P_0=32{,}409$ pounds$=14.468$ tons.
(4) $P_0=15{,}588$ pounds$=6.958$ tons.
(5) $P_0=12{,}904$ pounds$=5.760$ tons.

The allowable initial compression of the tube in state of rest is given by equation (34)—

$$P_1{}^1=(P_1+p_1)=13{,}228 \text{ pounds.}$$

Exterior pressure acting on tube in state of rest is from equation (33′a)—

$$P_1{}^1=P_1+p_1=7{,}689.8 \text{ pounds.}$$

Hence the values obtained above for P_0 are admissible.

The shrinkage of jacket above chamber is determined by equation (44); we have—

$$\varphi_1=0''.0013719.$$

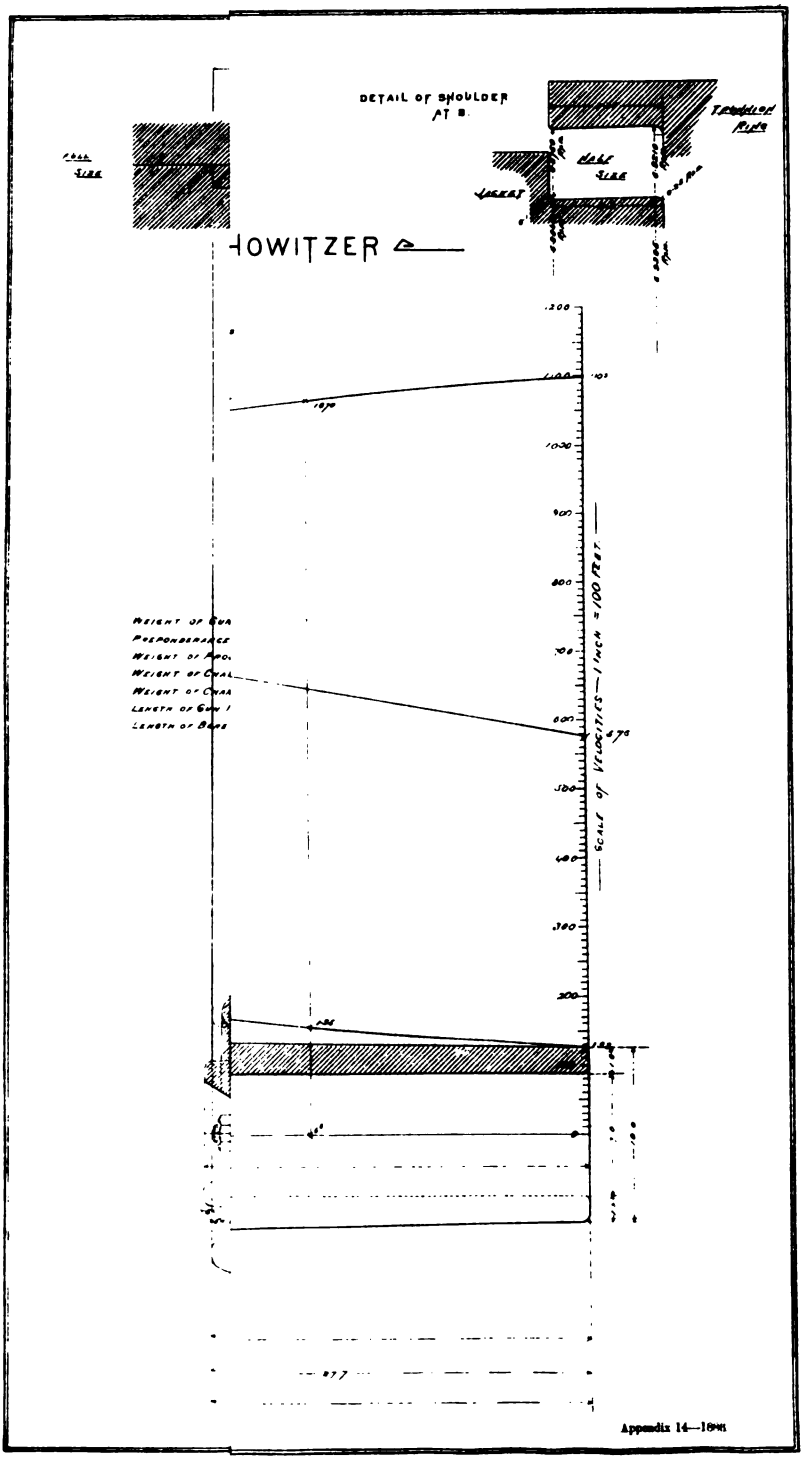
Absolute shrinkage$=\varphi_1\times 11''.66=0''.015996$.

Since the completion of the above the diameter given the chamber has been increased to 7″.2. This change will not materially affect the values obtained above.

The slight changes thereby necessary in the dimensions of the breech-block and base-ring have been allowed for in the accompanying tracing of the gun.

Very respectfully, your obedient servant,

WM. M. MEDCALFE,
Lieutenant of Ordnance.


DETAIL OF SHOULDER
AT B.
TRUNNION
RING
HALF
SIZE
JACKET
HOWITZER
1100
1000
900
800
700
600
500
400
300
200
SCALE OF VELOCITIES—1 INCH = 100 FEET.

APPENDIX 15.

EXPERIMENTS WITH BLASTING GELATINE BY THE ORDNANCE BOARD.

(1 plate.)

Four reports have been made on this subject, one having been forwarded April 7, 1883, a second, March 15, 1884, a third, October 11, 1884, and a fourth, July 7, 1885. These reports were accompanied by firing records, and gave in detail the kind of projectiles fired, and the results obtained. A summary will therefore be all that is necessary at present.

Ordnance Board Report No. 7, forwarded April 7, 1883, contained an account of experiments with camphorated explosive gelatine received from the Navy Department March 15, 1883. This was stated by Captain Selfridge to be composed of 88.66 per cent. of nitro-glycerine, 7.34 per cent. of soluble gun-cotton, 4 per cent. of camphor.

Five shell, charged each with 6½ ounces of the gelatine, were fired from the 3-inch wrought-iron field gun at a wrought-iron plate; all of these burst after leaving the gun and before striking the target. As the explosive had been on hand for some time before its receipt at the proving ground, a request was made that a similar substance, but uncamphorated, might be furnished.

Ordnance Board Report No. 19, forwarded March 15, 1884, contained an account of experiments with a new lot of the substance which had been received from General Abbot. It was manufactured by the Nobel's Explosive Company, of Glasgow, and is by them denominated "blasting gelatine." It is a jelly-like substance, of a straw-yellow color, containing 92 per cent. of nitro-glycerine, and 8 per cent. of soluble gun-cotton. It is shown by General Abbot, in a graphic comparison of various high explosives given in a plate facing page 30 of Addendum 2, of a "Report upon investigations to develop a system of submarine mines, &c.," to have an intensity of 142 as compared with nitro-glycerine, which is given in the same table as 81. According to this it is the most powerful of the 27 explosives therein tabulated. From its state of aggregation it is one of the least sensitive of the high explosives.

Two shell, with charges of this gelatine, were fired from the 3-inch wrought-iron field gun at a wrought-iron plate; one of these, as before, broke up after leaving the gun and before striking the plate; the second, containing a charge of 12 ounces of gelatine, did not take the grooves as was indicated by its striking sidewise. It broke on impact.

From the fact that six shell had burst after leaving the muzzle and before striking the target, while the seventh, which failed to take the grooves, did not burst until impact, it was believed that the rupture of the first six was due to heat generated by friction between the rotating projectile and the comparatively inert mass of contained gelatine; there-

fore 3 projectiles for a 3.2-inch gun were prepared with hollow cylindrical wooden cases closed at the bottom and lubricated on the exterior. Into each case one pound of the gelatine was packed. The first projectile did not explode until, having passed through a wooden screen 2 inches thick, it struck against a plate target. In the second, the wooden case was cracked while being filled, and the shell burst soon after leaving the muzzle of the gun; the third burst in the gun and destroyed it. This was the first indication that rupture might possibly ensue from the shock of discharge, as the projectile had apparently moved but little when it exploded. As, however, this projectile was an old one, and all the previous experiments indicated that the shock of discharge had not been sufficient to cause the ignition of the gelatine, it was believed that the injury was due to the rupture of the projectile by the powder charge or to the bad fitting of a base screw which had permitted the inflamed gases to reach the contents of the shell. It was recommended that new projectiles, specially prepared for the purpose, might be fired from an 8-inch muzzle-loading rifle.

Ordnance Board Report No. 26, forwarded October 11, 1884, contained an account of the experiments with these projectiles.

They were made of cast iron and had the ogival head connected to the body by a screw-thread. To avoid friction between the gelatine and the walls of the rotating shell, the explosive was packed into a thick cylindrical pasteboard case closed at the bottom and divided longitudinally into four compartments, formed by two pieces of wood intersecting and at right angles to each other. The outer edges of these wooden pieces were let into grooves cut in the pasteboard cylinder. The cylinder fitted the shell cavity loosely and was coated on the exterior with tallow and plumbago. The first shell thus prepared contained 5 pounds $3\frac{3}{16}$ ounces of gelatine and had a hollow rubber buffer 6 inches long, 1 inch thick, and closed at both ends, interposed between it and the charge of powder, the charge being 40 pounds of Du Pont's sphero-hexagonal K. H. B. The shell struck the target, burst on impact, and broke up into small fragments. An indentation about 7 inches deep was made in the plate. A second shell, prepared in a similar manner, except that the wooden diaphragm was omitted, was then fired and burst near the muzzle of the gun. A third shell, arranged exactly as the first one, that is, containing a pasteboard case with its wooden diaphragm, did not burst until the target was struck. These three rounds seemed to indicate that the case was superfluous, and that a stout diaphragm which would cause the gelatine to rotate with the shell would enable the substance to be fired safely. A fourth round was then fired with a copper diaphragm let into longitudinal grooves formed in the sides of the cavity. This shell contained 8 pounds 13 ounces of gelatine, was fired with a 40-pound charge of sphero-hexagonal powder, and did not burst until impact.

These records then appeared to indicate that there was but little danger of explosion of the gelatine from the shock of discharge. The injury to the wrought-iron target, composed of 3 plates each 4 inches thick, was not as great as that inflicted by an ordinary 8-inch chilled shot containing a bursting charge of rifle powder. From their mode of construction these shells were not very strong, and it was requested that six steel shell, each with a solid head and having the base of the cavity closed by a heavy screw plug for convenience in inserting the gelatine, might be obtained; the request having been granted, the shell were procured from the Mulvale Steel Company.

In the mean time a section of a wrought-iron turret prepared some years ago by the United States Engineer Corps had been transferred to the Ordnance Department and erected at Sandy Hook. It consisted essentially of 7-inch wrought-iron plates bolted together to form two thicknesses.

Ordnance Board Report No. 11, forwarded July 7, 1885, contained an account of the firing with steel shell. The first steel shell was without a bursting charge, was fired against the target June 12, 1885, struck it obliquely, and was broken into small fragments. The second shell, also without a bursting charge, struck head on, penetrated to a depth of 9¼ inches, rebounded, and was found to be practically uninjured.

A third shell was then grooved on the interior to hold the edges of a copper diaphragm, filled with a charge of 5 pounds of blasting gelatine, fired with a powder charge of 40 pounds of F. V. M. hexagonal powder and destroyed the gun. The gelatine had been on hand for more than a year, and it was thought possible that it might have deteriorated; furthermore, as it was uncamphorated, it was not considered that a satisfactory trial had been made of the best obtainable high explosive, and the Board in its report of July 7, 1885, stated that possibly camphorated gelatine might be more uniform in its action. This completes a summary of the experiments and reports made up to July 7 of last year.

Extracts from the records forwarded with these reports showing the action of all the shells fired with gelatine are given in the following:

Table of the results obtained at Sandy Hook up to July

Number of series.	Gun.	Number of round.	Date.	Charge. Kind.	Charge. Weight.	Projectile. Kind.	Projectile. Weight.	Charge of gelatine.	When reported.
			1883.		*Pounds.*		*Pounds.*	*Lbs. ozs.*	
1	8-inch muzzle-loading rifle No. 965.	783	Mar. 16	Mortar ...	1	Dyer percussion shell with Schenko percussion fuse.	9	— 6½	April 7, 1883.
2		784	Mar. 16	Du Pont's I. K. A. Density, 1.725; granulation, 2,200.	3		9	— 6½	
3		788	Mar. 28	Du Pont's I. K. B. Density, 1.725; granulation, 2,200.	3	Plunger removed from fuse.	9	— 6½	
4		789	Mar. 28		3		9	— 6½	
5		790	Mar. 28		3		9	— 6½	
			1884.						
6		794	Feb. 27	Du Pont's I. K. B. Density, 1.725; granulation, 2,200.	2	Butler shell. Hotchkiss fuse without plunger.	9¾	*	March 15, 1884.
7		796	Feb. 27		2		9¾	— 12	
8	8.2-inch breech-loading rifle No. 774, chambered.	873	Feb. 28	Du Pont's I. K. B. Density, 1.725; granulation, 2,200.	2	Hotchkiss shrapnel case.	11	1	March 15, 1884.
9		879	Mar. 8		2	Gelatine contained in wooden case.	10½	1	
10		880	Mar. 8		2		10½	1	
11		881	Mar. 8		2		10½	1	

7, 1885, *with shells containing blasting gelatine.*

Remarks.

Fired at iron plate. Shell found at plate broken into very small fragments—plate spattered with lead from sabot. Indentation slight.

Fired at iron plate and through a wooden screen placed between gun and plate. Shell broke up at or near muzzle.

Fired over water.

Burst at or near muzzle.

* Shell loaded with explosive gelatine. Fired at iron target 70 yards from muzzle of gun to ascertain if shock of firing would explode gelatine. Shell exploded at or near muzzle of gun.

Fired at iron target 70 yards from muzzle of gun to ascertain if shock of firing would explode gelatine. Shell exploded on striking target. A wad of tow half filling a 3-inch cartridge bag was interposed between shell and cartridge. The shell struck target sideways, producing an appreciable indentation. The heads of the shells used in these rounds (794 and 796) were screwed to the body for the sake of convenience in introducing the gelatine. The gelatine sticks (in paper wrappers) were loaded in the shell as compactly as could be done by hand, and the head of the shell was filled with cotton waste.

Fired at iron target distant 70 yards from gun to ascertain if shock of firing would explode gelatine. Shell exploded at or near muzzle of gun. Gelatine packed in shell as compactly as possible by hand. Paper coverings removed from sticks of upper layers and head filled with cotton waste. A tow wad was inserted between base of shot and cartridge.

Fired at iron target distant 70 yards from gun to ascertain if shock of firing would explode gelatine. Gelatine packed in an inner wooden case as compactly as possible by hand. Paper coverings removed from sticks of upper layers and head of shell filled with cotton waste. A tow wad was inserted between base of shot and cartridge. The inner case was of pine wood and was so fitted to the cavity of shell to admit free motion within it. Walls of cavity and inside and out of wooden case smeared with paraffine and black lead.

Round 879.—Shell passed through wooden screen 2 inches thick without bursting. Burst on striking target.

Round 880.—Burst at or near muzzle.

Round 881.—Burst in gun. All that part of gun in rear of front of breech receiver was thrown uninjured to the rear, and rest of the gun was broken into six large fragments. The carriage was dismounted; both wheels entirely disabled; cheeks spread outward forward of the front transom 90°; reinforcing cheek and trunnion bed-plate broken.

Table of the results obtained at Sandy Hook up to July

Number of series.	Gun.	Number of round.	Date.	Charge.		Projectile.		Charge of gelatine.	When reported.
				Kind.	Weight.	Kind.	Weight.		
					Pounds.		*Pounds.*	*Lbs. ozs.*	
12	8-inch muzzle-loading rifle No. 7, B. L.	425	1884. July 8	Du Pont's sphero-hexagonal K. H. B. Density, 1.775; granulation, 123.	40	Shell, with detachable head.	$160\frac{1}{4}$	5 $3\frac{3}{16}$	October 14, 1884.
13		426	July 8		40		161+	5 $14\frac{15}{16}$	
14		427	July 10		40		$160\frac{5}{8}$	5 $10\frac{1}{2}$	
15	8-inch muzzle-loading rifle No. 7, B. L.	428	Aug. 23	Du Pont's sphero-hexagonal K. H. B. Density, 1.775; granulation, 2,200.	40	Shell, with detachable head.	$166\frac{1}{4}$	8 13	October 14, 1884.
16	8-inch muzzle-loading rifle No. 7, B. L.	434	1885. June 17	Du Pont's hexagonal E. V. M. Density, 1.750; granulation, 2,200.	40	Forged steel shell.	193	5	July 7, 1885.

7, 1885, *with shells containing blasting gelatine*—Continued.

Remarks.

Fired at iron target distant 383 feet from gun consisting of 10 inches of iron backed by 30 inches of oak, previously used in experiments with 15-inch S. B. gun.
Round 425.—Shell especially prepared, with detachable head for explosive gelatine, containing a paper case ½ inch thick, divided longitudinally in four sections by wooden partitions ½ inch thick, intersecting each other at right angles, extending, however, only to within ½ inch of bottom; resting on cork filling bottom of shell cavity. A rubber buffer (1 inch thick, 6 inches long, and 6 inches in diameter) was also interposed between cartridge and shell. The interior of shell, the cork, and surfaces of paper case were carefully smeared with plumbago and the explosive gelatine filled in compactly without removing paper from sticks. Small wads of waste were placed underneath and above the gelatine. The shell burst into small fragments after striking target. The head, a large portion of which was found in front of target, had penetrated to a depth of about 7 inches, leaving a fair impression, on the right side of which the outer 2-inch plate of target was somewhat cracked.
Round 426.—Shell prepared as in preceding round, except that the wooden partitions were omitted and that the interior surface of the paper case was not coated with plumbago. Shell burst at or near muzzle with so little comparative violence that large pieces of the paper case—the bottom almost entire—were picked up between gun and target. A portion of the base of shell, carrying about two-thirds of the sabot, struck target, making well-marked indentation.
Round 427.—Shell specially prepared and fired as in round 425, except that the gelatine in each partition was covered with pasteboard discs. Shell burst into small fragments after striking target, making penetration of 7 inches.

Fired at iron target distant 353 feet from gun, and shell exploded on impact. Shell divided into 4 longitudinal sections by diaphragms of sheet copper, and gelatine packed in by hand, a small pad of cotton waste being placed at bottom and top.

Fired at iron casemate target distant 305 feet from gun. Shell divided into 4 longitudinal sections by sheet-copper diaphragms, and gelatine packed in by hand, a small pad of cotton waste being placed at bottom and top. Gun burst, breaking into many small fragments from a plane passing through the front of the jacket to the muzzle collar.

The Chief of Ordnance directed that a supply of blasting gelatine containing 3 per cent. of camphor should be obtained from the Nobel's Explosive Company in Glasgow, and this having been received, a steel shell with a copper diaphragm and containing 5 pounds of the camphorated substance, was on June 15, 1886, fired against the 14-inch target.

This shell burst before reaching the muzzle of the gun. Its action, however, was sufficiently singular to require some special comment. The gun in this case was the 8-inch muzzle-loading rifle, converted, No. 5. As in all these guns the casing was of cast iron, the lining was a coiled and welded wrought-iron tube. After the injury to the piece it was found that the wrought-iron tube was swelled extensively, beginning at a point about 2 feet from the muzzle, the exterior casing having been split off from this point. To the rear of this point the gun was but slightly injured. This indicated that the explosion of the gelatine was not due to the shock of discharge, and that it was of a gradual nature, caused rather by rotation, sufficient heat to produce explosion not having been developed till the projectile had nearly reached the muzzle, an indication that seemed to be confirmed by an occurrence to be alluded to subsequently.

As the gun was still capable of further use for experimental purposes a second steel shell, having a bursting charge of gunpowder, was fired in order to ascertain if it was possible that the inflamed gas could insinuate itself along the screw-thread and rupture the shell. Such was evidently not the case, as this projectile (round 649 of the firing record of 8-inch muzzle-loading rifle, converted, No. 5) did not explode until impact against the target.

This completes, up to the present time, the experiments with projectiles very similar to those in ordinary use and explosive gelatine.

On July 7, 1886, a projectile devised by Mr. B. B. Hill, shown in the accompanying plate, was fired. A Butler shell was bored through the base until the cylindrical part of the interior cavity, 4″.91 in diameter, was reached. A female thread 2″.5 long was cut at the posterior extremity of the cavity, and four longitudinal grooves diametrically opposite each other 8″.25 long, 0″.15 wide, and 0″.125 deep were formed on the interior. A screw-plug with a head 6″.6 in diameter closed the shell-cavity, the head containing four screwed holes to receive the ends of as many rods 0″.75 in diameter and 9″ long. On these rods was secured an elastic buffer consisting of six felt discs each 1 inch thick, and having four perforations through which the rods passed, while at the base of the buffer a heavy iron plate, 1 inch thick, was passed over the rods, and supported firmly against the posterior felt disc by nuts. The forward part of the shell-cavity was provided with an elastic cushion formed of felt discs cut to conform to the cavity. Against this cushion was placed the smaller end of a brass case, which was the receptacle for a charge of explosive gelatine. A similar cushion was held firmly against the rear of this case when the screw-plug closing the cavity was turned home. Four studs projecting from points near the base of the case engaged in the longitudinal grooves previously described, and were intended to cause the case to rotate with the shell. There was furthermore an apparatus intended to effect the explosion of a fulminate, but subsequent remarks will show that no necessity existed for the use of this device, and it is not described. The base of the case was fastened to the body by a screw-thread, and when this was unscrewed the bursting charge could be inserted easily.

The felt cushion in rear of the case, and the felt buffer in rear of the shell, were intended to moderate the shock of discharge. The felt

cushion in front of the case was designed to delay for a short interval the explosion of the bursting charge, and thus insure a partial penetration of an armor-plate.

On July 7 Mr. Hill, the inventor, being present, the case was, under his supervision, filled with 5 pounds of camphorated gelatine. The different parts of the shell were assembled and placed with a charge of 40 pounds of Du Pont's E. V. powder in the 8-inch muzzle-loading rifle, converted, No 5, which had, as hereinbefore described, been injured.

When the charge was ignited the gun was shattered to fragments about a point, which showed that the projectile had not moved appreciably before the gelatine exploded the shell. From the complete destruction which ensued, the explosion of the substance was of a high if not of the highest order.

It is for this reason that the phenomena which occurred when the gun was first injured require a careful consideration. Had the first injury been due to the action of the shock of discharge upon the gelatine, the gun, instead of being swelled near the muzzle, would have been shattered at the seat of the projectile. As Mr. Hill's projectile had not moved, rupture in that case was not due to heat caused by rotation. It would seem, then, that the first injury to the gun resulted from a low order of explosion, caused by rotation of the walls of the projectile in contact with the contained mass of gelatine. This could not have occurred had the copper diaphragm been secured properly in the grooved walls of the shell. It seems to be a fair inference that a stronger diaphragm, composed of steel plates and with its edges inserted into deeper grooves, should be tried.

To sum up the results of experiments with explosive and blasting gelatine, we find that—

Seven 3-inch shells were fired without injury to the gun, six of which burst before striking the target, one burst on impact.

Four 3.2-inch steel shells were fired, two of which burst before striking the target, one burst on impact, and one burst in the gun, destroying it.

Four 8-inch cast-iron shells were fired without injury to the gun; one burst before striking the target, and three burst on impact.

Two 8-inch steel shells were fired, each of which injured the gun.

One Hill projectile fired, which injured the gun.

The records relating to the firing with camphorated blasting gelatine are herewith enclosed.

J. McALLISTER,
Colonel of Ordnance, President of the Board.
A. MORDECAI,
Lieutenant-Colonel of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with 8-inch muzzle-loading rifle, converted,

	Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.		Elevation.	Length of cartridge.	Wind, strength and direction.	Length of shell with buffer.
		1886.		Lbs.		Lbs.	Oz.	°	In.		In.
P. M.—Barometer, 29.930; thermometer, 74; humidity, 79.	649	June 15	Du Pont's E. V. M. Density, 1.750; granulation, 72.	40	Steel shell (refired) containing 5 lbs. blasting gelatine. Camphorated.	191	....	15	....	From front and left, 87°; 6 miles an hour.	......
P. M.—Barometer, 30.060; thermometer, 67; humidity, 93.	650	June 22	Du Pont's E. V. M. Density, 1.750; granulation, 72.	40	Steel shell (new) containing 4 lbs. 7 ozs. musket powder.	194	7	15	....	From front and left, 43°; 10 miles an hour.	......
P. M.—Barometer, 29.840; thermometer, 90; humidity, 54.	651	July 7	Du Pont's E. V. M. Density, 1.750; granulation, 72.	40	Hill's, containing 5 pounds blasting gelatine.	177	....	....	28	From rear and right 87°; 24 miles an hour.	29.5

No. 5, *at Sandy Hook, N. J., from June* 15 *to July* 7, 1886.

		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc.
Fired from cradle at iron casemate target distant 300 feet.	The shell cavity was divided by copper diaphragms into, 4 sections, into which the gelatine sticks were closely packed, a little pad of cotton waste being spread above and below. A paper cap was spread over the waste just before the breech plug, carefully smeared with white lead, was screwed home upon a copper washer. A hollow rubber buffer, diameter 6 inches, weight 8¼ pounds, was placed between cartridge and projectile.	Cast-iron muzzle blown off for a length of about 2 feet, leaving wrought-iron tube exposed and bulged. Parts of shell recovered down beach as far as mile target.
		Shell arranged precisely as in round No. 649, except that no rubber buffer was used. Penetrated 9 inches; burst violently; rear plate badly cracked.
Weight of brass case filled, 10 lbs. 8 oz.; weight of brass case empty, 5 lbs. 8 oz.; weight of gelatine, 5 lbs.	Fired from cradle at iron casemate target, distant 300 feet, to try Hill's projectile, consisting of a brass ogival-headed case containing the gelatine with a felt cushion in front surrounding a detonating stem and all inclosed in a cast-iron shell. A buffer was attached by bolts and washers to the rear of the shell, consisting of ten layers of red and white felt. The blasting gelatine, camphorated, was packed into the brass case by Mr. Hill, a disc of target paper being spread over the gelatine before the cap was screwed on. The breech-plug was smeared with white lead and screwed down upon a copper washer.	Shell exploded in gun, throwing front of tube, about 6′ 3″ in length, 15 yards to the front, turning it end for end; and base of tube projecting 5 to 14 inches from cast-iron body, about ten yards to the rear. Fragments of the cast iron were scattered about laterally. The position of the fracture of the tube showed that rupture took place at the seat of the projectile and 6 to 10 inches from the base of cast-iron shell.

APPENDIX 16.

STEEL AND WOODEN AMMUNITION-CHESTS BY THE ORDNANCE BOARD.

(6 plates.)

A letter dated May 28, 1885, from Colonel Mordecai, commanding the Watervliet Arsenal, to the Chief of Ordnance, suggested:

> That in order to obtain some data in regard to the advantage of using metal entire in the construction of ammunition-chests for the field service, one of the metal chests be subjected to experiment by the Ordnance Board. A chest of metal and one of wood could be loaded with cartridges, and projectiles prepared with powder and fuze, and be fired at with small-arm ammunition at ranges under 500 yards. * * *

This suggestion was approved by the Chief of Ordnance in his indorsement of June 6, 1885, and a steel chest was forwarded to Sandy Hook. It is supposed that the construction report from Watertown Arsenal will give details and drawings of the chest as completed. A perspective drawing not made to scale and only such points relating to the construction and arrangement as are required for the purposes of this report are furnished herewith.

The steel chest (Plate I) is made of plates about one-tenth of an inch in thickness, and is composed, essentially, of a top, front, and bottom plate, two end plates, and a back plate. The top plate, which serves as a seat, is curved and projects 0''.75 all around. Its edges are folded back, and at the front and ends they are bent downward and riveted to the corresponding edges of the front and end plates; at the rear the top plate is folded upon itself and secured by rivets. The front, bottom, and end plates are secured to each other by internal and external angle-irons riveted through and through. The back plate is secured to the bottom plate by hinges, which allow it to open backward and downward; it is supported when open by a chain at each end connected with the end plate and forms a table.

A partition one-tenth of an inch thick divides the interior of the chest into two equal parts. On the left side of the partition is a shelf six and one-half inches deep extending from front to rear. Beneath this shelf are four partitions extending from front to rear, dividing the space into five receptacles. In two receptacles are found zinc trays furnished with rings and a rubber sole. Each tray will hold five projectiles point down. Two similar trays are found in the next two receptacles, but while these each contain a rubber sole the rings are replaced by straw-board cylinders. In the last receptacle is a copper box intended to hold friction primers.

The right half of the chest has a shelf 9''.4 deep and the space below it contains two trays, one at the front, the other at the back. The rear tray, which is movable, contains ten straw-board cylinders in two rows of five each, intended to hold projectiles with their axes horizontal, instead of vertical, as in the first instance. The front tray is fixed and holds ten projectiles in two rows of five each. The supports for the projectiles are not, as in the rear tray, cardboard cylinders, but are formed by suitably bending and connecting zinc plates, in order that they may surround and retain the projectiles. The weight of the steel chest with partitions and trays was 316.5 pounds, without trays 253.5 pounds.

The wooden chest was of the kind used for the 12-pounder light gun. Its weight with partitions is 185 pounds.

The gun used in the experiments was the 0″.45 caliber 10-barrel Gatling gun No. 195.

The ammunition was the rifle-ball cartridges, model 1881.

The experiments commenced August 6, 1885. The steel chest was packed with twenty-six 3″.2 shell containing bursting charges and base fuzes, 14 case-shot with bursting charges, point and base fuzes, 40 cartridges each containing 3.5 pounds I. K. D. powder and 50 friction primers. The chest was placed at first 1,000 yards from the firing point. It was struck directly once, but as the indentation was slight it was brought to a distance of 800 yards from the gun. At 800 yards there were three direct hits but no penetrations. The distance was then diminished to 500 yards, when of 22 direct hits 2 only penetrated.

The final firing was carried on when the chest was placed 400 yards from the firing point. Thirty-six direct hits occasioned 15 penetrations of the chest, making with the 2 at 500 yards a total of 17 as shown on the plate numbered II.

The wooden chest was then packed with thirty 3″.2 shell, each containing a bursting charge and base fuze; ten shrapnel with bursting charges, point and base fuzes; twenty-eight cartridges each containing 3.5 pounds of I. K. D. powder, and fifty friction primers.

At 800 yards two direct hits were received by the chest, one on a strap which was indented, one on the side of the chest which perforated it.

At 500 yards of six direct hits one penetrated an iron strap, two penetrated the copper lid cover, and three penetrated the exposed side.

At 400 yards 23 direct hits perforated the chest, two passing through both sides.

The total number of penetrations in this chest was 28, and their location is shown on Plate III.

As the number of hits on the wooden chest at the 800-yard range was but two it was concluded to repeat the firing at that distance. In this series there were 15 hits and 9 penetrations. The chest was empty. The location of the shots in the last series is shown in Plate IV.

When the bullets entered either the steel or wooden chest and struck cartridge-bags the powder was scattered but no explosion resulted. When the brass heads or point fuzes of the shrapnel were struck the head was indented and the fuze was broken, but no explosion occurred. The following table recapitulates the results obtained:

Table showing effect of rifle-ball cartridges, model 1881, fired from a 10-barrel Gatling gun at steel and wooden field ammunition-chests.

Kind of chest.	Distance.	Hits.	Penetrations.	Remarks.
	Yards.			
Steel	1,000	4	0	1 direct; 3 ricochet.
Steel	800	3	0	
Wood, 1st series	800	2	1	1 indented strap.
Wood, 2d series	800	15	9	5 through and through. Of the 6 that failed to penetrate 5 struck iron parts and 1 struck lid.
Steel	500	22	2	2 imbedded in chest.
Wood	500	6	4	2 passed through copper lid cover.
Steel	400	36	15	
Wood	400	23	23	2 through and through.

As it was difficult to strike the projectiles when in the chest, six shell with base fuzes and six shrapnel with base and point fuzes were placed in an open case 400 yards distant from the gun. Half of each had their points and half their bases toward the firing point. The shell when struck on the head were uninjured, when struck on the base the fuze was bruised if struck by the bullet, but was in no case exploded.

When struck by bullets the brass heads of the shrapnel were bruised and their point fuzes were broken but not exploded.

When the shrapnel were struck on the base, one wing of the plunger which actuates the point fuze was broken, but the other wing was uninjured and no explosion occurred; the fuze was still serviceable.

It may be said, therefore, that with field projectiles and their ammunition packed in either steel or wooden ammunition-chests there is at 400 yards and upward but little danger of explosion when the chests are perforated by ordinary bullets. Explosive bullets could be specially made for operating against field ammunition-chests, but would probably be of such a size and made from such material as would insure the penetration of steel chests at 800 yards, unless the thickness of the plates is materially increased, which would be impracticable.

It is believed that shell or shrapnel at 800 yards would destroy a steel chest almost as readily as a wooden one.

Comparing these chests in other respects it appears that the steel one weighs with its partitions 316.5 pounds, the wooden one 185 pounds, a difference of 131.5 in favor of wood.

Perforations in the wooden chest could be easily repaired and made water-tight in the field; perforations in the steel chest could not.

The cost of the steel chest, even when made in large numbers, would be greater than that of the wooden chest.

RECAPITULATION.

(1) If shell, shrapnel, or specially prepared explosive bullets are used, either steel or wooden chests would be destroyed at 400 yards.

(2) At 400 yards the wooden chest is more readily perforated by bullets than the steel one, but such perforations are unlikely to cause explosion.

(3) The wooden chest is much lighter than the steel chest.

(4) The wooden chest can be repaired in the field more readily.

(5) The wooden chest is less expensive than the steel one.

For all these reasons the Board sees no advantage in using steel in the construction of field ammunition-chests, and recommends that hereafter they be made of wood.

A photograph (Plate V) gives a more graphic representation of the effect of the bullets upon the steel chest, and the photograph, Plate VI, shows the effect upon the cartridge-bags.

The firing records are inclosed herewith.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with Gatling gun No. 195 (10-*barrel*) *at*

[To determine at what distances steel ammunition-chest would resist the penetrative force of a 500- tents of the chest when

	Number of fire.	Time.	Ammunition.	Wind; strength and direction.
		1885.		
P. M.—Barometer, 30.071; thermometer, 75.4; humidity, 55.	12	Aug. 6	Frankford Arsenal 500-grain bullet.	From rear and left, 48°; 12 miles an hour.
	160	Aug. 6		
Barometer, 30.089; thermometer, 69.7; humidity, 74.	5	Aug. 7		From front and left, 87°; 12 miles an hour.
	80	Aug. 7		
	5	Aug. 7		
	140	Aug. 7		
	5	Aug. 7		
	100	Aug. 7		

[To ascertain effect on wooden ammunition-chest, the

	Number of fire.	Time.	Ammunition.	Wind; strength and direction.
P. M.—Barometer, 30.153; thermometer, 65.0; humidity, 56.	25	Sept. 2	Frankford Arsenal 500-grain bullet.	From rear and right, 43°; 14 miles an hour.
	75	Sept. 2		
	20	Sept. 2		
	75	Sept. 2		
	15	Sept. 2		
	50	Sept. 2		
A. M.—Barometer, 30.052; thermometer, 62.1; humidity, 87.	1,350	Sept. 30	Frankford Arsenal 500-grain bullet.	From front and left, 87°; 3 miles an hour.

Sandy Hook, N. J., from August 6 to October 23, 1885.

grain bullet, the following shots on August 6 and 7 were fired; also to ascertain the effect on the com-
penetration was obtained.]

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.

Sighting shots.

1 direct and 3 ricochet hits. None penetrated chest, distant 1,000 yards from gun.

Sighting shots.

3 direct hits, none of which penetrated chest, distant 800 yards from gun.

Sighting shots.

22 direct hits, 2 of which penetrated chest and 2 embedded in chest, distant 500 yards from gun.

Sighting shots.

36 direct hits, 15 of which penetrated chest, distant 400 yards from gun. Two cartridges badly broken and powder mealed; 11 other cartridges slightly injured.

The ammunition-chest fired at was received July 14, 1885, from Watervliet Arsenal and made of $\frac{1}{16}$-inch steel. The chest contained, when fired upon, 26 3.2-inch shells, loaded and having base fuse, 14 case shot, with bursting charge and fuze, 40 3.2-inch cartridges (each containing $3\frac{1}{4}$ pounds I K D powder) and 50 friction-primers.

following shots were fired at it from Gatling gun.]

Sighting shots.

2 direct hits, one of which penetrated chest and the other indented iron strap, distant 800 yards from gun.

Sighting shots.

6 direct hits, one of which penetrated iron strap, 2 penetrated copper lid cover, and then penetrated chest, breaking up one cartridge, distant 500 yards from gun.

Sighting shots.

23 direct hits, 2 of which went through and through chest—cartridges badly broken up—distant 400 yards from gun.

The chest contained when fired at 10 loaded 3.2-inch shrapnel, with fuze; 30 loaded 3.2-inch shell, with fuze; 28 cartridges, each $3\frac{1}{4}$ pounds I K D powder, and 50 friction-primers.

Fired at wooden box placed 400 yards from gun, and containing 6 3.2-inch shrapnel, with Hotchkiss base and Frankford Arsenal brass-point fuze; also 6 3.2-inch shell, with Hotchkiss base fuze. The points and bases of the shrapnel and shell were arranged in box so as to be alternately exposed to the firing.

Record of firing with Gatling gun No. 195 (10-*barrel*) *at Sandy*

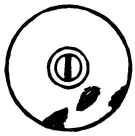
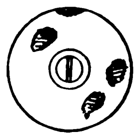
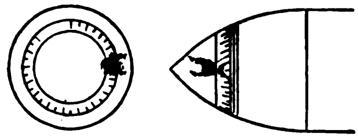
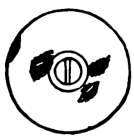
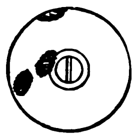
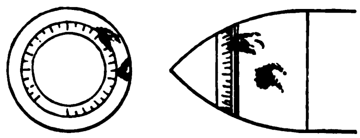
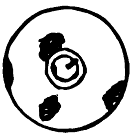
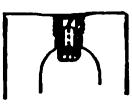
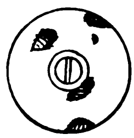
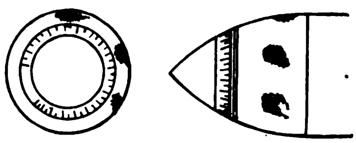
Shells with point towards gun.
Struck 4 times on or about head. Fuse uninjured.
Struck 4 times on or about head. Fuse uninjured.
Struck 3 times on or about head. Fuse uninjured.

[To ascertain effect on wooden ammunition-chest the following

	Number of fire.	Time.	Ammunition.	Wind; strength and direction.
		1885.		
P. M.—Barometer, 29.797; **thermometer,** 58; **humidity,** 72.	366	Oct. 15	Frankford Arsenal 500 grain bullet.	**From rear and right 87°; 15 miles an hour.**
P. M.—Barometer, 30.092; **thermometer,** 55.3; **humidity, 56.**	363	Oct. 23		**From front and left 43°; 8 miles an hour.**

3,721 rounds fired from above gun.

Hook, N. J., from August 6 to October 23, 1885—**Continued.**

Shells with base towards gun.	Shrapnel with base towards gun.	Shrapnel with point towards gun.
 Struck 3 times. Fuze uninjured.	 Struck 4 times on base; one wing broken from plunger of point fuze, but percussion composition uninjured. Base fuze uninjured.	 Struck once on point. Base fuze uninjured. Point fuze broken, but plunger uninjured.
 Struck 4 times. Fuze uninjured.	 Struck 4 times on base; one wing broken from plunger of point fuze, but percussion composition uninjured. Base fuze uninjured, but bruised.	 Struck 3 times on point. Base fuse uninjured. Point fuze broken in two places on graduated ring as shown, but plunger was uninjured.
  Struck 4 times. Head of base fuze sheared off. Wire of plunger exposed and disturbed, but percussion composition uninjured.	 Struck 4 times on base; one wing broken from plunger of point fuze, but percussion composition uninjured. Base fuze uninjured, but bruised.	 Struck 3 times on head, which was indented as shown. Point fuze uninjured. Base fuze uninjured.

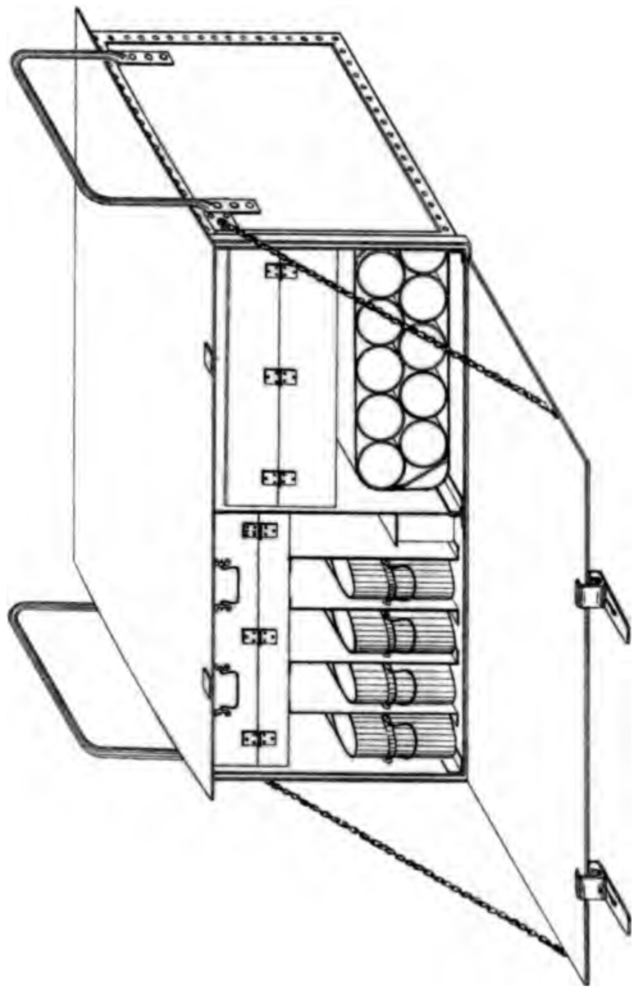
shots were fired at it from Gatling gun (chest unpacked).]

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.

1 direct hit (not plotted). Chest distant 800 yards from gun.

15 direct hits, 5 of which passed through and through chest; 3 perforated exposed side, 5 struck iron parts and failed to perforate, and 1 grazed lid; 1 penetrated iron part to base of bullet. Chest distant 800 yards.

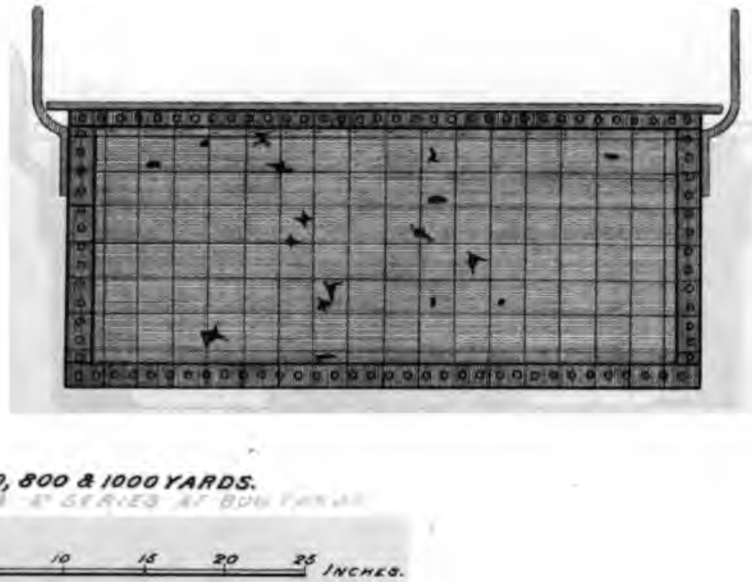
ISOMETRIC VIEW OF STEEL AMMUNITION CHEST



Appendix 16—1886.

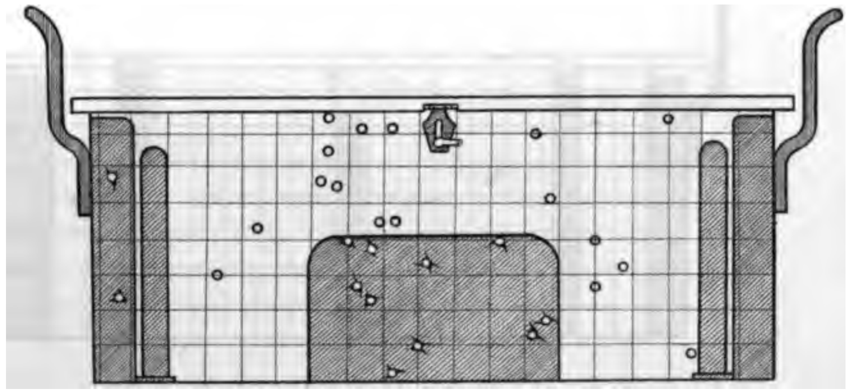
PLATE II.

STEEL AMMUNITION CHEST



400, 500, 800 & 1000 YARDS.

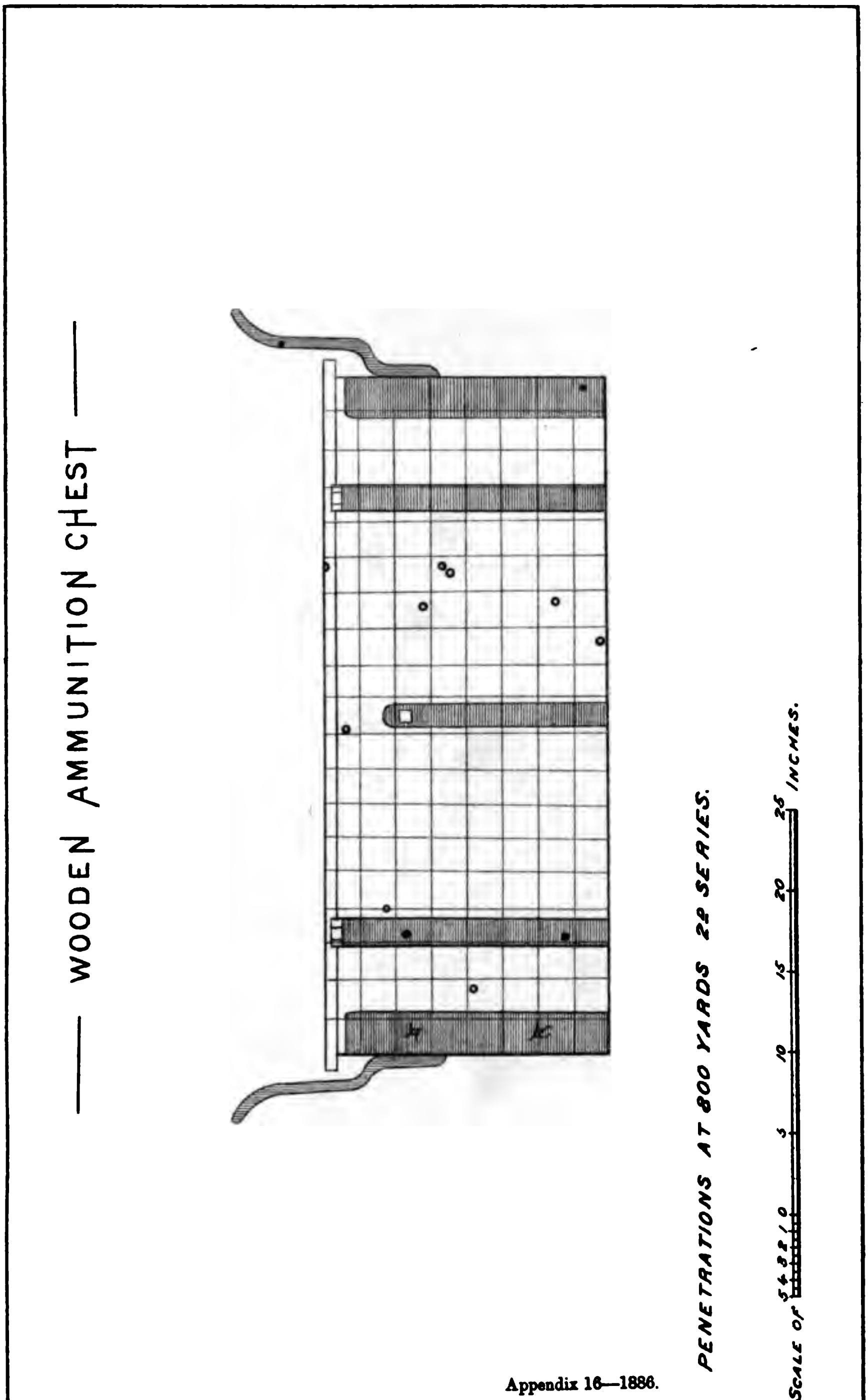
WOODEN AMMUNITION CHEST



ITIONS AT 400,500 & 1ST SERIES AT 800 YARDS.

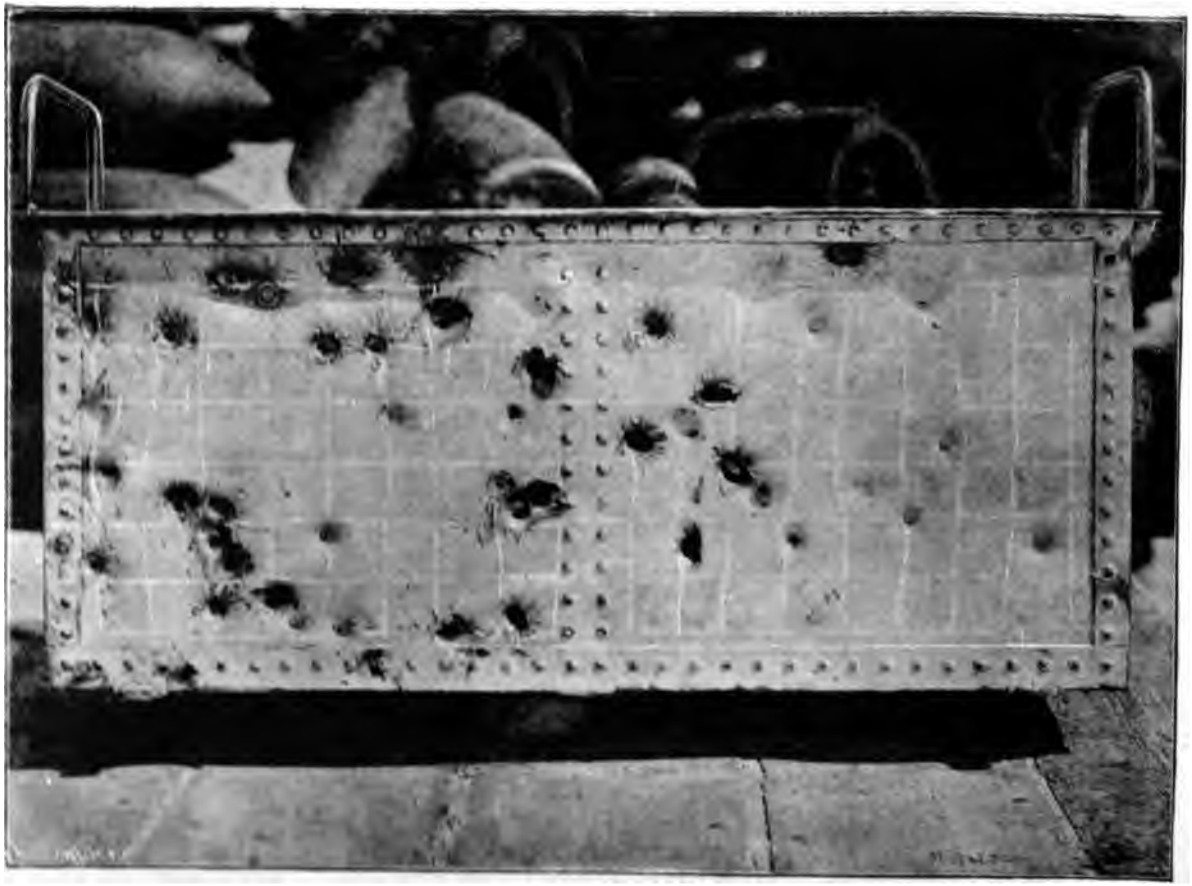
ILE OF 5 4 3 2 1 0 5 10 15 20 25 INCHES.

PLATE IV.



Appendix 16—1886.

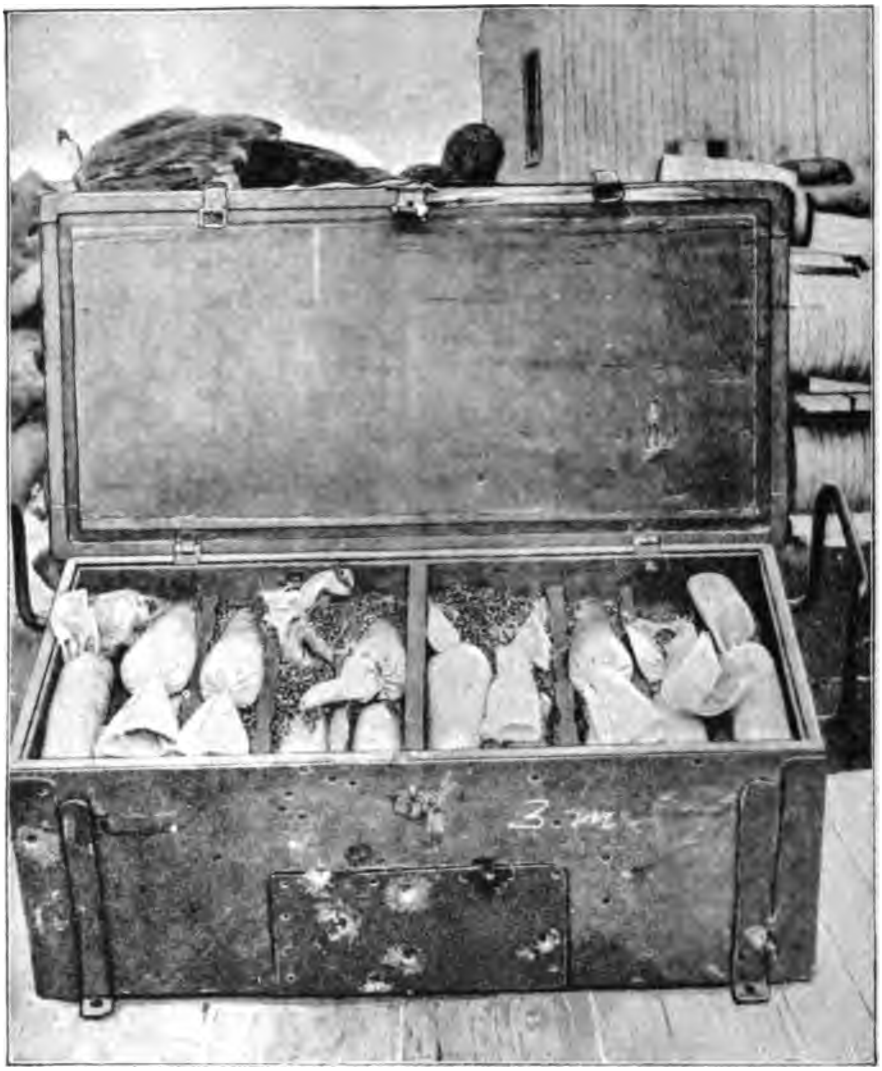
PLATE IV.



EFFECT OF BULLETS ON STEEL CHEST.

[Appendix 16—1896

PLATE VI.



EFFECT OF BULLETS ON CARTRIDGES.

Appendix 16—1886.

APPENDIX 17.

REPORT UPON THE CONSTRUCTION OF EXPERIMENTAL STEEL 8-INCH BREECH-LOADING RIFLE No. 1.

BY CAPT. ROGERS BIRNIE, JR., ORDNANCE DEPARTMENT.

(7 plates.)

List of plates.

I. Outline and sectional dimensions of gun.
II. Rifling: details of hoop-joints, longitudinal coupling-pins, and outline of front of chamber.
III. Sectional and rear view of breech mechanism.
IV and V. Details of parts of breech mechanism.
VI. The steel forgings and test specimens.
VII. Stages of assemblage.

The construction of this gun, which is the first sea-coast cannon composed wholly of steel manufactured under the auspices of the Ordnance Department, U. S. Army, was authorized by the act of Congress approved March 3, 1883. Steps were promptly taken to carry out the provisions of the act, as shown in the Report of the Chief of Ordnance for 1883, page 5 *et seq.* On the 3d of April, 1883, a circular letter stating the nature and dimensions of the steel forgings required was "distributed to more than twenty of the principal steel works in the United States." The Chief of Ordnance further stated in his report above quoted, page 10:

The replies to this letter were, with one or two exceptions, adverse to undertaking such work, arising, I presume, from want of skill and knowledge in the treatment of steel for gun construction and from the want of the requisite plant to perfect the forgings. The conclusion reached was that the plant or the experience in this country cannot as yet produce the steel forgings, for tube and jacket, for so large a gun as an 8-inch caliber. The tubes and jacket required for the 8 and 10 inch steel guns have therefore been ordered from Sir Joseph Whitworth & Co., England.

The steel hoops required for the banded guns being of comparatively small mass and readily produced from an ordinary tire-mill, their manufacture has been undertaken by the Midvale Steel Company, of Philadelphia. Three experimental hoops were ordered from this company for test, in order to ascertain how nearly they could come up to the requirements of the Department's circular letter. Two of these hoops were of the largest size that will be required for the experimental guns, and one was annealed after rolling, while the other was oil-tempered and annealed. The third hoop was hammered and oil-tempered, being of the size required for the smaller hoops of the 8-inch gun, which are not sufficiently large to admit of being rolled in the mill at the Midvale works.

The results obtained from the mechanical tests of these hoops, both by traction and by hooping tests (see Appendices 41 and 42), show that they are fully equal in quality to the best hoops of European manufacture.

The manufacture of the steel forgings being well under way, a contract was made in June, 1884, with Paulding, Kemble & Co., for the fabrication of the gun at the West Point Foundry, Cold Spring, N. Y. These contractors agreed to machine-finish and assemble the gun, and supplied a few of the minor parts of the breech mechanism. Every stage of the work was followed and inspected by an officer of the Ordnance Department on duty at the works. The resident inspector, Lieut. F. E. Hobbs, at the Midvale Steel Works, followed the manufacture of the hoops at that place and supervised the tests of the metal upon which the acceptances were based. The steel forgings for the tube, jacket, and trunnion hoop, supplied by Sir Joseph Whitworth & Co., were also carefully tested by the Department before their acceptance. The Midvale Steel Company completed their portion of the work first, and the forgings for the plain hoops and breech-block were delivered from their works at the West Point Foundry in October, 1884. The delivery of the order from Sir Joseph Whitworth & Co. was completed in February, 1885. The gun itself was completed at the West Point Foundry in June, 1886. The data furnished by the inspection report of the gun rendered at that time form the basis of this paper. (See Appendix 18, Report of the Chief of Ordnance, 1886.)

Before proceeding to a description of the gun and its manufacture, I will enumerate briefly the careful steps taken by the Ordnance Department to lead up to the manufacture of the gun with the most complete knowledge possible. They consisted (1) in the establishment of a high standard for the physical qualities of the steel, (2) in preliminary tests of different qualities of steel to determine whether it would be best to use the metal simply annealed or annealed and oil-tempered, and (3) in a preliminary construction of an actual section of the gun over the powder chamber, to make a practical test of the qualities of the metal used in the construction of the gun and of the theoretical principles to be applied. Meantime the theory of the shrinkages—so important in reaching a conclusion that would bring about the development of a maximum resistance for the gun when fired—was studied and discussed. The tests already referred to (see Appendices 41 and 42, Report of the Chief of Ordnance, U. S. Army, 1883) established the excellent quality of the hoops furnished by the Midvale Steel Company, and led to the adoption of oil-tempered steel. A study of the shrinkages to be applied in constructing the experimental-chamber section of the gun was then published in "Notes on the Construction of Ordnance," No. 31, and a report upon the actual construction of the section in the same series, No. 32. In applying the principles of Clavarino in this practical test the results were so satisfactory that the Department felt no further hesitation about proceeding with the construction of the gun upon the same basis. Thereon was based the study, published in "Notes on the Construction of Ordnance," No. 33, which had for its object the determination of the shrinkages best adapted to give a maximum resistance in the different parts of the gun. Due regard was paid to the compression of the bore of the tube in contiguous sections where, owing to changes in the thickness of the superincumbent metal, it became necessary, as far as possible, to avoid planes of torsional strains. The conclusions reached by this study were adopted and followed in constructing the gun.*

* The only changes of consequence made after this time were the omission of the screw coupling between tube and jacket, and the substitution therefor of the four coupling pins (see Plate II); also, the introduction of a ninth hoop in the C row, and of the lap joint in the same row at the junction of the single with the double row of hooping in the chase of the gun.

DESCRIPTION OF THE GUN.

(Plates I, II, III, IV, and V.)

The gun is an 8-inch steel breech-loading rifle, of 30 calibers length of bore, and weighs 13 tons. It is designed to fire a projectile weighing 285 pounds with a charge of 100 pounds of slow-burning powder, giving a density of loading equal to 0.9. The body is built up with the several layers of cylinders or hoops of oil-tempered gun-steel superimposed and shrunk one upon another, with tensions adapted to develop in common, as nearly as practicable, the elastic strength of each row of metal when the gun is dilated by the firing. The effect of this division of the gun into layers is to increase the calculated elastic resistance of the gun about 86 per cent. over what it would be if the body were a solid piece of metal of a uniform strength throughout equal to that of the present jacket cylinder. But in fact the building-up principle has this much more in its favor, viz, that the working of the metal in comparatively small masses renders it far more homogeneous and gives it greater strength.

The principal parts of the gun are, (1) the tube, (2) the jacket, (3) the four pins which couple the tube and jacket together longitudinally, (4) the A row of twelve hoops, (5) the B row of ten hoops, (6) the C row of nine hoops, (7) the D row of three hoops, and (8) the breech mechanism, which is modeled after the De Bange system. The principal dimensions are as follows:

1. Diameter of bore across lands	inches.	8.0
2. Number of grooves and lands		45
3. Width of lands	inches.	0.17
4. Width of grooves	do..	0.3884
5. Depth of grooves	do..	0.06
6. Diameter of shot recess	do..	8.19
7. Diameter of chamber	do..	9.5
8. Length of chamber	do..	49.75
9. Length of shot recess and slope	do..	4.39
10. Length of 8-inch rifled bore	do..	191.51
11. Volume of powder chamber*	cubic inches.	3,107.
12. Total volume of bore*	do..	13,169.
13. Number of volumes of expansion		4.24
14. Thickness tube over powder chamber	inches.	2.275
15. Thickness of jacket	do..	3.975
16. Thickness of A hoops	do..	2.15
17. Thickness of B hoops	do..	2.6
18. Thickness of tube at front of hooping	do..	3.875
19. Thickness of tube at muzzle	do..	2.5
20. Diameter to bottom of thread in breech-screw	do..	11.04
21. Diameter to top of thread on breech-block	do..	11.0
22. Height of screw-thread	do..	0.27
23. Pitch of screw-thread	do..	0.75
24. Length of screw-thread	do..	11
25. Number of smooth and threaded sectors each		3.
26. Exterior diameter of gun over reinforce	inches.	31.5
27. Distances between faces of rim bases	do..	34.0
28. Diameter of trunnions	do..	10.0
29. Length of unhooped portion of tube at muzzle	do..	91.09
30. Total length of tube	do..	245.65
31. Length of jacket shrunk on tube	do..	87.36
32. Total length of jacket	do..	99.86
33. Total length of A row, 12 hoops	do..	97.0

* The first set of these figures gives the *initial volume*, or that in which the powder charge is confined when the piece is loaded. The space (2.1 cubic inches) occupied by the heads of the pressure plugs used for experimental firing has been deducted. The second set of figures gives the *final volume*, or whole volume, of bore, including the 201.75 cubic inches of groove space.

34. Total length of B row, 10 hoops	do..	85.5
35. Total length of C row, 9 hoops	do..	67.14
36. Total length of D row, 3 hoops	do..	32.0
37. Length of gun, axis of trunnions to breech	do..	81.96
38. Length of gun, axis of trunnions to muzzle	do..	176.25
39. Total length of gun over all, breech closed	do..	271.71
40. Weight of breech block, obturator, and lever, complete	pounds.	434.0
41. Weight of body of gun without breech mechanism	do..	28,930.0
42. Weight of gun complete	do..	29,544.0
43. Breech preponderance 53 inches in rear of center of trunnions		204.0

The rifling has an increasing twist. Beginning with 1 turn in 70 calibers at the origin, it increases to 1 turn in 25 calibers at 16 inches from the muzzle, and thence is uniform with the same pitch to the muzzle.

The tube has a total length of 245.65 inches; its maximum diameter is 15.75 inches plus the shrinkage over a length of 67.14 inches between the muzzle end of the jacket and the forward end of the hooping; thence, to the muzzle, the length is 91.09 inches, and the exterior of the tube has a straight taper which forms the chase of the gun. To the rear, for the remaining length, the tube is seated in the jacket. There are three shoulders on this portion of the tube, arranged to make the necessary changes of diameter gradual. The angles of metal at these shoulders are rounded and filleted, and in assembling the tube and jacket a clearance was left at the two within the jacket, and also at the breech end of the tube to insure contact at the shoulder at the muzzle end of jacket with the object of making the construction as stiff as possible. The breech end of the tube is free, and has to support only such small part of the longitudinal strain produced by the pressure on the bottom of the bore when the gun is fired as is communicated by the friction of the gas-check pad and the friction due to the stretch of the jacket on the exterior of the tube. The tube—of all the cylinders in the system—is subjected to the most severe tangential strain, and it is of great importance to relieve it from this longitudinal strain. The open end of the breech is flared with a straight taper to form a seat for the gas-check and to facilitate its withdrawal. The straight portion of the chamber (39.15 inches) is connected with the slope at its front by rounded angles, and the front of the slope is joined in the same way with the shot-recess to reduce scoring from the gases. The length of the shot-recess is such that the base of the projectile in place projects 0.25 of an inch within the slope of the chamber. The rifling grooves are filleted with circles of 0.08 of an inch radius and the edges of the lands are parallel.

The jacket, 99.86 inches in length, is about 3 inches shorter than the design of the gun called for. Over the greater portion the exterior diameter is 22 inches plus the shrinkage, but a shoulder, 3 inches wide and 0.6 of an inch high, is found near its forward end to receive, through the intermediate hoop A, the forward thrust of the trunnion-hoop due to the discharge, and thus prevent the trunnion-hoop from starting forward; hence the jacket, which also carries the breech-block, has mainly to support the longitudinal strain on the gun. The muzzle end in front of this shoulder is considerably reduced in thickness to receive the binding effect of the hoop D and the overlap of A, and thus stiffen the gun. The jacket projects 12.5 inches in rear of the tube and is there bored out and threaded to receive the breech-block. The threaded portion of this bore is 11 inches in length, leaving a blank space of 1.5 inches next the base of the tube to relieve the conjunction of the torsional with the longitudinal strain at the first thread of the screw, where the latter strain is especially severe. The two shoulders in the jacket,

at and near the breech end of the tube, cause a gradual reduction in the thickness of the wall and give no special angle of weakness. Assuming, however, that if rupture took place at all it would occur near the bottom of the first shoulder from the breech, we have there a fillet with a radius of 0.6 of an inch, and the thickness of the wall of the jacket is 4.475 inches. At the second shoulder the wall is reduced to its uniform minimum thickness of 3.975 inches, the cross-sectional area of metal is there equal to 225.1 square inches, and even with a pressure of 45,000 pounds (about 20 tons) per square inch on the head of the block the strain per unit of area on the cross-section would be only 14,105 pounds per square inch, whilst the elastic limit of the jacket metal, determined by tests of specimens taken longitudinally from the breech end, is 50,000 pounds per square inch nearly.

The pins.—The details of the longitudinal coupling pins are shown in Fig. 5, Plate II. Each pin is driven into its seat with a close air-tight fit and is secured in place by a screw-cap 1.0 inch thick, to counteract any tendency to work outward. The pins pass through the wall of the jacket and into the wall of the tube 0.375 of an inch. The combined area of the four pins to resist shearing, in case the tube should slip forward in the jacket, is 12.57 square inches, and as the pins may be relied upon to offer a resistance of 90,000 pounds per square inch to shearing, the aggregate resistance becomes 1,131,300 pounds, which is more than one-third of the aggregate pressure (3,189,700 pounds) that the assumed pressure of 45,000 pounds per square inch in the chamber would produce on the bottom of the bore. The object of inserting these pins was simply to counteract the first tendency of the tube to slip, but they afford, *per se*, sufficient strength to materially assist in maintaining the tube in position. The four pins are in the same cross-section of the jacket wall, and the area of metal cut away for their insertion, in a section embracing the width of the pins, is about 11.6 per cent. of the whole area of the jacket in the same section. The holes were bored after the jacket was shrunk on the tube. The bore of the tube was carefully measured before and after the boring, and no appreciable relaxation of the compression was found consequent upon the boring. The probable explanation of this is that the tangential tension of the jacket being comparatively light, and the holes being placed at a distance from the muzzle end, the removal of 11.6 per cent. of the metal in a 2-inch band was not appreciable. It is considered that the insertion of the pins has not appreciably lessened the tangential strength of the gun in their vicinity.

The main reliance to prevent such slipping of the tube is the friction between the tube and jacket. The area of the surface of contact between these two pieces, where the jacket is shrunk upon the tube, is 3,816 square inches. From careful computation, verified by experiment, the aggregate *normal* pressure over this contact surface is 62,785,000 pounds, nearly, at the minimum stage, that is, when the system is at rest. If we take only 10 per cent. of this to represent the resistance due to the friction,* we would have a force of over 6,000,000 pounds to resist slipping of the tube. With 45,000 pounds per square inch pressure on the bottom of the bore the aggregate would be 3,189,700 pounds, and if the combined effect of the inertia of the tube with its superincumbent weight forward of the jacket, the forward pressure and friction of the gases, and of the shot were to produce a forward pull on the tube to the same amount, the resistance offered by the friction would still be

* Recent experiment has shown that 15 per cent. would be somewhat below the true value of this factor in the case under consideration.

nearly double the effort tending to slide the tube. When the gun is fired the pressure at this contact surface becomes at least doubled, but the uncertain nature of friction in the presence of vibrations in the metals makes it desirable to introduce a positive means of connection, which the pins afford.

The hooping.—The A and B rows form the double layer of hooping over the reinforce of the gun, the latter being outside. The hoops in each row abut end to end, and form a straight cylindrical interior surface, except the forward hoop of the inner row, hoop A_1, which is counterbored to give a shoulder to bear against the one on the jacket. The principal use of the hooping is to give tangential strength to the gun, but the joints are broken to give longitudinal stiffness, and also to distribute and equalize the tangential resistance. The counterbore of the hoop A_1 extends over the shoulder of the jacket and laps 2.5 inches on the hoop D_1, covering also the joint between the rear face of the D hoop and the front face of the jacket shoulder. The trunnion hoop, B_1, is made heavy enough to support the weight of the gun; this hoop is assembled under shrinkage in common with the rest of the row and has to afford a share in the tangential resistance; it is effectually prevented from stripping forward as before mentioned. At the rear, the A row extends flush with the face of the jacket and the B row is foreshortened 3.5 inches; the extremity of each is rounded to a curve formed by tangent circles. The rim bases of the trunnions are filleted to a circular form like the cast-iron guns in service. The exterior of the hoop A_1 forms the first frustum of the chase in front of the trunnions.

The C and D rows of hoops cover the remainder of the hooped portion of the chase. The interior of each row forms a continuous, straight cylindrical surface. In order to break the joint at the front end of the D row, where the double hooping ends, the hoop C_4 is counterbored and laps 2.5 inches over the reduced exterior of the adjoining C hoop. The shortness of the hoop C_1 arises from the necessity of inserting this length of hoop to make up for the deficiency in the length of the jacket. The D row, at the front, abuts against a shoulder formed by the increased thickness of the C hoop which is at the base of the single row of hooping. The hoop D_1 presses upon the caps of the coupling-pins, for which purpose the shrinkage surface adjoining those pins, including to tops of the caps, was not finished until after the caps were inserted. The exteriors of the D row and of the C row in the single hooping are frustrums of right cones rounded only towards the front. These exteriors form respectively the second and third frustums of the chase of the gun, whilst in the fourth or muzzle frustum the tube stands alone. The hoops generally in this gun are shorter than those which will be used in future constructions when increased facilities for manufacture shall be available. It was necessary in this case to use a tire rolling mill, and the hoops were made as wide (long) as the machinery would admit.

The breech mechanism is shown in detail in the drawings—(Plates III, IV and V)—except the gas-check pad, which was left to be made and fitted at the Proving Ground. Leaving out the pad, the four principal movable parts of the breech mechanism are: (1) the breech-block, (2) the spindle, of which the mushroom-shaped obturator head forms part, (3) the lever, and (4) the console or swinging tray with its appendages movable and fixed. The parts fixed to the gun are: the hanger, the stop-stud, and the lever-head recess. All the parts are made of forged and tempered steel, except as follows: the washer under spindle nuts, of copper; the hanger, of a very clean and fine quality of wrought iron;

and the tray proper, of a composition casting containing 55 parts of copper, 44.5 of zinc, and 0.5 of tin.*

The breech-block is threaded, and three sectors of the thread are removed to correspond to the thread and sectors of the screw in the jacket. When slid in or out the thread sectors of the block pass through the smooth sectors of the jacket, and the rear thread on the block is left full to arrest the block at the proper point of insertion where the threads are in position to engage, and one-sixth of a turn to the right fully engages them. In this operation the block is carried forward 0.125 of an inch and the gas check pad is forced into place. The clearances of the threads and over the smooth sectors of the block and jacket, made to give a free and easy movement, are all shown in detail upon the drawing, Plates III and IV. The handles are in one piece with the block, being cut and shaped from the solid metal.

The spindle, perforated by the axial vent, passes through the center of the block, which is fine-bored to receive it. The forward end of the vent is bushed with copper, and the diameter of the vent through the copper is 0.1 of an inch, whilst for the remainder it is 0.2 of an inch. Two adjustable nuts and a copper washer are placed upon the spindle and covered in a space counterbored in the rear of the block. The position of these nuts is regulated by the thickness of the gas-check pad, and they have reverse threads to cause a lock and hold them in position.† The mushroom-shaped head of the spindle covers the gas-check pad and in the discharge presses upon the pad and forces it out laterally to check the escape of gas. As first made the rear of the vent was left plain to use the ordinary primer, but this will be changed, after some preliminary firings have been had, to use an obturating primer.

The lever is pivoted and supported between the handles of the block by a bolt which passes through them and around which the lever revolves. The lever has three functions, viz: when the handle is upright it serves to revolve the block, either in the motion of locking or unlocking; again, when the block is turned to the locked position the eccentric of the lever is turned down and revolves into the recess cut in the breech of the gun, thus preventing the accidental unlocking of the block; and finally, in unlocking when the block is turned back ready to be withdrawn, a downward motion of the lever causes its eccentric to press against the flat surface of the breech and affords great power to start the block out. When the block is out the lever hangs freely downwards, and when the block is locked the lever is closed on the breech, as shown in Fig. 1, Plate III, with the handle engaged in the catch-spring attached to the tray.

When the block is withdrawn for loading it rests upon the console and is otherwise wholly detached from the gun. The use of the console is to provide a suitable support for the block to enable it to be swung to one side (the right) and clear the breech for the insertion of the projectile and powder charge. The console is attached to the breech face of the gun by means of the hanger, which is dovetailed and bolted to the breech and the staunch hinge-bolt which passes through the hub

*The tests of a bar of metal 3.0 inches between gauge marks and 0.564 of an inch in diameter, cut from this casting, gave the following results, viz: Elastic limit 17,000, and ultimate resistance 63,000 pounds per square inch; relative elongation at elastic limit, 0.1467, and after rupture, 19.0 per cent.; reduction of area after rupture, 21.4 per cent.

†This arrangement is only provisional, and will be subject to modification after the gun has been fired experimentally.

and is held by a set-screw. In the swinging movement, then, the bolt revolves with the consoles in its bearings through the ears or lugs of the hanger. The upper surface of the console is accurately dished to the diameter of the rear portion of the block recess, and sits flush with it, so as to support the block during the withdrawal. On this upper surface also there are two guide-rails of a clutch form upon which the block engages through two longitudinal grooves of corresponding form. The motion of the block over the console is arrested when the ends of these grooves strike against the forward ends of the rails, but the momentum communicated by the shock causes the latch of the console to be released below, and the withdrawal of the block and swinging it clear becomes practically one continuous motion. The latch which serves to hold the console in position to withdraw or insert the block is seated in a recess on the under side. As shown in the drawing, Fig. 2, Plate III, it is in this position engaged in the catch-bolt which is screwed into the breech of the gun, and is held there by the latch-spring. The latch revolves about the bolt near its center, which passes through flanges of the console. When released from the catch-bolt, *i. e.*, when partly swung around, the *upper* beak is thrown upward by the action of the spring and engages in the recess shown in the block and prevents the block from slipping forward whilst resting on the console. The spring which engages the shank of the lever when the block is locked is screwed fast to the console (see Fig. 1, Plate III). For inserting the charge a loading-tray is used. It is not shown in the drawings, but is a segment of a cylinder made of copper, which is fitted in the breech recess to cover the threads and form a smooth passage-way from the breech into the chamber.*

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* The following is an interesting discussion of the theory of the latch:

THEORY OF THE LATCH.

[Translation by Lieut. D. A. Howard, U. S. Ordnance Department, pp. 460–464 "*Traité de balistique rationnelle*," *par J. Baills, lieut. de vaisseau.* Paris, 1883.]

The console is held in contact with the breech face of the gun by a latch (loquet), which is shown in profile, Fig. 76.

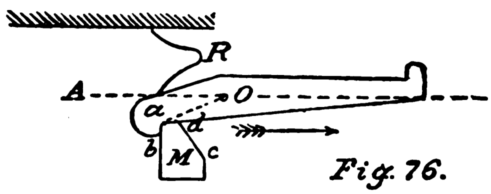

Fig. 76.

When the breech-block is drawn to the rear, in the direction of the arrow, it abuts against the stops arranged on the clutches (rails) of the console. The quantity of motion impressed upon the block is then transmitted to the console and consequently to the axis of rotation, O, of the latch, since this axis forms part of the console. The beak of the latch *ab*, pressed against the face of the catch M, rises, sliding on this face, until it becomes disengaged, notwithstanding the resistance of the spring R.

To elucidate the theory of this apparatus, let us suppose it reduced to its geometrical elements, which are: The center of rotation O, the arm O*a*, and the surface of contact, *ab*. The face, *ab*, which is vertical when at rest, becomes more and more inclined as the beak rises and the angle AO*a* diminishes. At first, the whole face, *ab*, is in contact; then the contact is changed to a horizontal line of the face only;

The operation of the breech-mechanism is as follows: Supposing the block locked, as shown in Fig. 1, Plate III, to withdraw the block and make ready for loading, (1) seize the lever by the handle and revolve it upward through an arc of 180 degrees, (2) use the lever in the new position to revolve the block one-sixth of a turn or until the head of its pivot-bolt strikes the stop-stud, (3) press, the lever downward to start the block to the rear and lower the handle until it rests upon the rear edge of the console, (4) grasp the handles and withdraw the block, exerting enough force towards the end of the slide to give a quick and decided motion, the effect of which will be to start the console and release the latch, then a continuation of the motion will swing the console with the block to the position for loading. After the projectile and powder charge have been inserted and the loading-tray withdrawn, to lock the block, (1) grasp the handles of the block and swing the console back to position, when the latch will fasten itself, (2) raise the lever to an upright position and let an assistant hold it there and then slide the block forward until it is stopped by the full thread at the rear coming to its bearing, (3) use the lever to revolve the block one-sixth of a turn, or until the ear of the handle strikes against the bevel on the upper lug

however, the pressure and friction will remain unaffected by the extent of surface pressed.

At any instant, then, of the period of unlatching, we have (Fig. 77) Oa, the arm

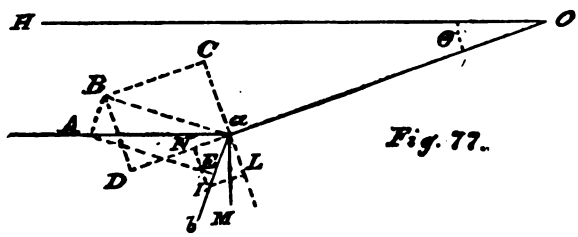

Fig. 77.

of the latch; ab, the beak; ω, the angle of construction; Oab, θ, the angle that the arm Oa makes at the given instant with the horizontal line OH, which represents the direction of the force of traction.

Without changing the conditions of the problem, we can suppose the point O to be fixed, and that the catch aM is moved horizontally to meet the face ab. Let a be the projection of the horizontal line of contact and aA=F the force developed, which we will resolve into the components aB and aE. This last component, tangential to ab, is without effect. The normal component aB furnishes two others, one, aD, in the prolongation of Oa, which is opposed by the direct resistance of the pivot; the other, aC, is perpendicular to the arm of the latch, and its intensity determines the instantaneous rotation of the beak around the point O, and consequently the progessive liberation of the latch, we have

$$aC = aB \sin(\omega - 90^\circ)$$
$$aB = F \cos BaA$$
$$\text{angle } BaA = baM = baM = \omega - 90^\circ - \theta$$

then

$$aC = F \sin(\omega - 90^\circ) \cos(\omega - 90^\circ - \theta)$$

and the moment with respect to the axis of rotation is obtained by multiplying this force into is lever arm Oa=l.

We pass now to the moments which are opposed to rotation. The friction developed by the pressure of the normal force aB on the beak is measured by

$$aB \times f = f\, F \cos(\omega - 90^\circ - \theta)$$

this friction which we represent by the line at aI is resolved into aN and aL. The

of the hanger, (4) revolve the lever downwards until the shank is engaged in the catch-spring. The closing of the breech mechanism will be facilitated by slightly depressing the muzzle of the gun.

The carriage intended to be used in the experimental firings with this gun is a 10-inch proof carriage recently constructed after the designs of the Department, under contract, at the West Point Foundry. It is fully described in a report rendered by Lieut. D. A. Howard, Appendix 20, Report of the Chief of Ordnance, United States Army, 1886. This carriage is adapted to the 8-inch gun by the insertion of two steel trunnion rings, or bushings, which rest in the trunnion beds and are bolted to the cheeks of the carriage and supported below by braces similarly attached.

THE ELASTIC STRENGTH, SHRINKAGES, AND COMPRESSION OF THE BORE.

The following table gives a summary of the results obtained from tests of bars of metal taken from the principal forgings used in the gun:

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first is destroyed by the fixed pivot, the second is directly contrary to the force aC: $aL=aI \cos(\omega-90^\circ)=fF\cos(\omega-90^\circ)\cos(\omega-90^\circ-\theta)$: he lever arm is still Oa.

Finally, calling P the weight which suspended at the point of pressure of the spring would produce exactly the same effect and b the horizontal distance from the axis O to this point of suspension the resisting moment of the spring will be $P \times b$.

Let us place:

α= angular velocity of rotation of the latch.

m = mass of latch.

ρ = radius of gyration with respect to the point O. We will have for the equation of the motion

$$\frac{d\alpha}{dt}=\frac{aC\times l-aL\times l-P\times b}{m\rho^2}$$

$$=\frac{F\cos(\omega-90^\circ-\theta)\left[\sin(\omega-90^\circ)-f\cos(\omega-90^\circ)\right]-Pb}{m\rho^2}$$

The angle θ continually diminishes as the latch is being liberated, then, if the motion can be started its continuation will be assured. Now, at starting off we have $\theta=\omega-90^\circ$, and the corresponding angular acceleration is

$$\frac{d\alpha}{dt}=\frac{F\left[\sin(\omega-90^\circ)-f\cos(\omega-90^\circ)\right]-Pb}{m\rho^2}$$

which should be positive in order that the rotation may begin.

It is evidently necessary to have $\sin(\omega-90^\circ)-f\cos(\omega-90^\circ)>O$, whence $\tan(\omega-90^\circ)>f$. Let us make f=0.115 the coefficient of friction of iron upon iron we will have $(\omega-90^\circ)>9^\circ$, consequently if ω is less than 99° the latch will not lift up however great may be the force of traction and though the spring be set aside.

On the other hand if ω is greater than this limiting value the liberation will always be obtained, whatever may be the power of the spring, on applying sufficient force, and if the spring did not exist the slightest force would suffice to cause the motion.

At setting off the face, ab being vertical the angle HOa should, from what has just been said, be greater than 9°.

In the reverse operation, which consists in returning the breech-screw to its position of obturation, the exterior curve of the stud pushed from right to left strikes the inclined plane cd, ascends sliding along this plane, and after having cleared the upper edge falls again to its position of rest.

It is in order to assure this fall, which would be opposed by the friction of the pivot O, that the spring R is inserted. If the power of the spring required for the security of the operation involves by way of compensation a too considerable increase of the force F it is easy to remedy this inconvenience by opening still more the angle $\omega-90^\circ$; it is easy to see, indeed, that the acceleration $\frac{d\alpha}{dt}$ is nearly directly proportional to this angle, since, at the beginning of the movement, the angle $\omega-90^\circ$ being quite small the cosine varies very little, while the sine increases almost proportionally with the arc.

TABLE I.—*Tests of the metal on bars cut from the rough-finished forgings.*

Subject of measurement.	Tube forging, Whitworth steel (specimens taken tangentially).			Jacket forging, Whitworth steel (specimens from breech end).			
	By tension.		By compression.	By tension.		By compression.	
	Breech end.	Muzzle end.	Breech end.	Tangential specimens.	Longitudinal specimens.	Tangential specimens.	Longitudinal specimens.
Number of specimens tested	2	3	3	2	3	2	2
Diameter of specimen bars ... inches..	0.564	0.564	0.798	0.564	0.564	0.798	0.798
Length of bars between gauge marks ... do...	3.0	2.0	5.0	3.0	2.0	5.0	5.0
Elastic limit ... pounds per square inch..	35,000	53,330	35,000	52,500	53,000	50,500	47,000
Relative elastic displacement ... thousandths..	1.35	1.517	1.242	1.734	1.717	1.667	1.533
Resistance at failure on primitive section ... pounds per square inch..	82,880	99,790	....	93,780	94,080	83,140	85,080
Relative elongation after rupture ... thousandths..	201.6	238.6	....	210.0	230.0	....	....
Area of primitive section ... square inches..	0.25	0.25	0.5	0.25	0.25	0.5	0.5
Reduction of area after rupture—per cent. of primitive section	33.5	40.0	....	39.2	51.3	....	....

Subject of measurement.	Plain hoops, Midvale steel (specimens taken tangentially).						Trunnion hoop, Whitworth steel (specimens taken tangentially).
	Hammered hoops (C and D rows).			Rolled hoops (A and B rows).			
	By tension.		By compression.	By tension.		By compression.	By tension.
Number of specimens tested	2	6	2	8	16	4	3
Diameter of specimen bars ... inches..	0.564	0.564	1.132	0.564	0.564	1.129	0.564
Length of bars between gauge marks ... do....	3.0	6.0	9.0	3.0	6.0	9.0	6.0
Elastic limit ... pounds per square inch..	65,000	63,170	60,000	62,250	61,750	61,750	36,330
Relative elastic displacement ... thousandths..	2.1	2.022	2.033	1.975	1.975	1.946	1.567
Resistance at failure on primitive section ... pounds per square inch..	115,520	113,880	....	105,730	107,390	....	86,690
Relative elongation after rupture ... thousandths..	162.0	123.0	....	178.8	139.4	....	173.9
Area of primitive section ... square inches..	0.25	0.25	1.007	0.25	0.25	1.0	0.25
Reduction of area after rupture—per cent. of primitive section	36.4	37.8	....	42.5	42.9	....	50.5

From the results of these tests the values given in the following table were selected to represent the safe elastic *working limits* of the metals in the structure; that is to say, the limits to which the metals might be allowed to work in the most severely strained state to which the cylinders would be subjected individually or collectively, either with the system at rest or in action. The moduli of elasticity are assumed to be constant up to the points of strain indicated:

TABLE II.

Cylinders of the gun.	Elastic limit (load per square inch).		Elastic displacement.	Modulus of elasticity (load per square inch).	
	Pounds.	*Tons.*	*Thousandths.*	*Pounds.*	*Tons.*
Tube	49, 600	22. 143	1. 6	31, 101, 600	13, 840
Jacket	44, 800	20. 0	1. 445	31, 101, 600	13, 840
Hammered hoops:					
Used as under row in double hooping	52, 640	23. 5	1. 645	32, 000, 064	14, 286
Used as single row outside over tube	51, 520	23. 0	1. 610	32, 000, 064	14, 286
Used as outer row in double hooping	48, 832	21. 8	1. 526	32. 000, 064	14, 286
Rolled hoops:					
Used as under row in double hooping	54, 390	24. 28	1. 7	32, 000, 064	14, 286
Used as outer row in double hooping	50, 000	22. 32	1. 5625	32, 000, 064	14, 286
Special for hoop A, outer row	51, 520	23. 0	1. 61	32, 000, 064	14, 286
Trunnion hoop	35, 840	16. 0	1. 493	24, 000, 000	10, 714

The values selected for the tube approach more nearly the physical characteristics of the muzzle end. They were used principally because the shrinkages for the gun had already been computed for a different tube having the qualities named, but it was believed that the qualities shown by the tests from the muzzle end warranted their use with this tube, and the successive compressions of the bore of the gun measured during its manufacture, by their agreement with the anticipated (theoretical) values, indicate the approximate correctness of the assumption made.

For the jacket and the plain hoops the values are well within the limits determined by the free tests (see Table I). The values for those hoops which were used in the outer rows are reduced still more, inasmuch as these cylinders have no exterior support in the structure, and it is considered desirable to place their working limits at least 10 per cent. below the elastic limits determined by the free tests of the metals.

Tests of the metal of the trunnion hoop made by the manufacturer gave much better results than those recorded in Table I, but the tests therein recorded were used to guide in the work, and, in addition, this hoop was assembled with a shrinkage somewhat lighter than the computed shrinkage.

Reference has already been made to the published account of the computations for the shrinkages of the gun based on the previously recorded tests. See "Notes on the Construction of Ordnance," No. 33. We will, therefore, review the matter here only so far as is necessary to give in this connection the salient points regarding the elastic strength of the gun—especially the tangential resistance—together with a comparison of the actual with the computed shrinkages and of the actual with the anticipated compression of the bore in the completed gun.* The comparisons will be useful in substantiating the correctness of the theories upon which the computations are based, and also for reference in future constructions.

* For the partial compressions of bore, measured during the several stages of the manufacture, see Addenda III, Appendix 18, Report of the Chief of Ordnance, 1886.

The results are given in the following table, in which the computed data, that is, the values given in the first half are taken from the table on pages 26 and 27, "Notes on the Construction of Ordnance," No. 33. The computations were made and the comparison of results is given for twelve sections through the hooped portion of the gun as designated:

TABLE III.—*Elastic tangential resistance of gun, shrinkages and compression of bore.*

Sections of the gun.	Computed values.										
	Elastic tangential resistance (pressure per square inch), P_0	Shrinkages.						Compression of bore.			
		First.		Second.		Third.		Breech of jacket.		Bore of tube.	
		Relative ϕ	Absolute.	Relative ϕ	Absolute.	Relative ϕ	Absolute.	Relative $\frac{\Delta R_0}{R_0}$	Absolute.	Relative $\frac{\Delta R_0}{R_0}$	Absolute.
Breech:	*Tons.*	*Thou.*	*In.*	*Thou.*	*In.*	*Thou.*	*In.*	*Thou.*	*In.*	*Thou.*	*In.*
Single hooping	......	1.494	0.0329	......	......	......	......	0.5586	0.0057	......	......
Double hooping	......	1.494	0.0329	0.5415	0.0142	......	......	0.750	0.0077	......	......
Breech of tube	24.76	0.78051	0.010	1.494	0.0329	1.2972	0.0341	......	......	1.60	0.0152
Powder chamber	24.774	0.85594	0.012	1.494	0.0329	1.2972	0.0341	......	......	1.60	0.0152
Between chamber and trunnion hoop	24.87	0.85594	0.012	1.494	0.0329	1.2972	0.0341	......	......	1.527	0.0122
Trunnion hoop	24.55	0.85594	0.012	1.494	0.0329	1.2972	0.0341	......	......	1.483	0.0119
Base of hoop A	23.00	0.85594	0.012	1.4044	0.031	......	......	......	......	1.250	0.010
Shoulder of jacket (within front edge)	22.72	0.85594	0.012	1.4044	0.0326	......	......	......	......	1.200	0.0096
Forward end of jacket (within face)	21.563	0.85594	0.0125	1.3645	0.027	......	......	......	......	1.078	0.0086
Middle of D row of hoops	20.775	1.000	0.016	1.2416	0.0246	......	......	......	......	0.950	0.0076
Base of C row (single hooping)	17.55	1.000	0.016	......	......	......	......	......	......	0.510	0.0041
Hoop C_3 (end of cone)	16.83	1.000	0.016	......	......	......	......	......	......	0.435	0.0035

Sections of the gun.	Measured values and variations from computed values.										
	Shrinkages.						Compression of bore.				
	First.		Second.		Third.		Breech recess of jacket.			Bore of tube.		
	Actual.	Absolute variation.	Actual.	Absolute variation.	Actual.	Absolute variation.	Actual.	Variation.		Actual.	Variation.	
								Absolute.	Relative.		Absolute.	Relative.
Breech:	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*Thou.*	*In.*	*In.*	*Thou.*
Single hooping	0.033	0.	......	......	......	......	0.004	−0.0017	0.16	......	......	....
Double hooping	0.033	0.	0.016	+0.0018	......	......	0.008	+0.0003	0.03	......	......	....
Breech of tube	0.010	0.	0.033	0.	0.034	0.	......	......	....	0.0167	+0.0015	0.19
Powder chamber	0.0123	+0.0003	0.0335	+0.0006	0.0331	−0.001	......	......	....	0.0154	+0.0002	0.025
Between chamber and trunnion hoop	0.0135	+0.0015	0.0338	+0.0009	0.0337	−0.0004	......	......	....	0.0137	+0.0015	0.19
Trunnion hoop	0.0135	+0.0015	0.0335	+0.0006	0.0311	−0.003	......	......	....	0.0128	+0.0009	0.11
Base of hoop A	0.014	+0.002	0.032	+0.001	......	......	......	......	....	0.0121	+0.0021	0.26
Shoulder of jacket (within front edge)	0.013	+0.001	0.0335	+0.0009	......	......	......	......	....	0.0122	+0.0026	0.325
Forward end of jacket (within face)	0.011	−0.0015	0.027	0.	......	......	......	......	....	0.0104	+0.0018	0.225
Middle of D row of hoops	0.016	0.	0.0246	0.	......	......	......	......	....	0.0085	+0.0009	0.11
Base of C row (single hooping)	0.017	+0.001	......	......	......	......	......	......	....	0.0060	+0.0019	0.24
Hoop C_3 (end of cone)	0.017	+0.001	......	......	......	......	......	......	....	0.0036	+0.0001	0.01

The gun is designed to afford abundant elastic resistance to the powder pressures within the hooped portion. Throughout the reinforce and forward, to include the trunnion hoop, it will support an interior pressure of 24.5 tons (about 55,000 pounds) per square inch without exceeding the elastic limit of any of the component cylinders. Similarly, the double-hooped frustrum of the chase will support, in round numbers, a pressure of 20 tons, and the single-hooped frustrum 16 tons per square inch on the bore surface. With a suitable powder the desired ballistic effect can be obtained from this gun under a maximum pressure limited to 16 tons per square inch. Thus the gun has one-third more elastic resistance than it will under normal conditions of firing be called upon to exert. The elastic tangential resistance of the unhooped portion of chase is computed to be 11.58 tons at the base and 9.53 tons at the muzzle, and the factor of safety within the elastic limit for anticipated pressures is at no point less than 2. The only apparent source of danger for the unhooped chase lies in the possibility that the metal of the tube may not be of uniform strength throughout. The computations depend upon tests of specimens cut from the muzzle end, and these tests show an unusually fine quality of metal. If the chase were hooped its safety would be reasonably assured, for the hoop metal is worked in small masses, and the weak places of the tube forging, if there be any, would be strengthened by re-enforcing it with hoops.

Reference has already been made to the elastic longitudinal resistance of the gun against deformation or rupture at the breech. The cross-section of the jacket metal which opposes this strain, on the supposition that the strain is uniformly distributed, would be worked to less than one-third its elastic strength if the pressure in the bore reached 45,000 pounds per square inch.

In what precedes it is assumed that the anticipated strength of the gun has been realized in its manufacture. A proof that such an assumption is safe is afforded by the comparison of the prescribed and actual shrinkages and of the anticipated and actual compression of bore given in Table III. The summation of the result is shown by the compression of the bore, wherein the measured compression is nearly the same as the anticipated, or differs from it only within such limits as may be allowed and even expected in such extended applications of the formulas, involving a great number of measurements made with different instruments and at different times. In regard to the measurements, however, care was taken to refer always to the standard—a 36 inch vernier beam caliper—and the instruments used were supplied with verniers and graduated to read 0.001 of an inch. Finally, in connection with the proof already adduced, it will be recalled that the sufficiency of the theories in the formulas made use of in computing the data for the construction of this gun has been demonstrated by careful experiment. Indeed, considering the apparent intricacy of the problem, the application of the formulas supplies a surprising agreement between theory and practice. This much has been practically demonstrated, and the greatest difficulty in constructing guns of this class lies not in the theory of the construction, but in the practical operations, that is, in machining and finishing the parts with the nicety required, and in a skillful and careful measurement of the finished surfaces, with a view to such correction of the finished dimensions as may be necessary in order to attain the desired end, namely, a very close agreement of the actual dimensions with those prescribed. Whatever gauges the workmen may use, it is best to adopt the rule that a finished piece should not be removed from the lathe until its dimensions have been verified by the inspector.

INCIDENTS OF MANUFACTURE.

The methods and appliances of manufacture, although governed in some essential particulars by the stipulations of the contract, were left mainly in the hands of the contractors. The duties of the inspector involved the measurements of the finished work, and a detailed examination of its accuracy in all stages of the construction; his approval in these respects constituted a necessary antecedent to the continuation of the work at all times. The following order was observed in the general operations attending the manufacture (see Plate VII):

1. Hoops and jacket prepared for shrinkage. Fig. 1.
2. Tube prepared for shrinkage. Fig. 2.
3. Jacket and hoop C_1, to C_{3a}, inclusive, shrunk on tube.
4. Holes for coupling-pins drilled and pins inserted.
5. Shrinkage surface finished for D row of hoops. Fig. 3.
6. D row of hoops shrunk on.
7. Shrinkage surfaces finished for A row of hoops and lap of hoop C_4. Fig. 4.
8. A row and hoop, C_4 to C_8, inclusive, shrunk on.
9. Shrinkage surface finished for B row of hoops.
10. B row of hoops shrunk on
11. Chamber and bore fine bored and finished.
12. Screw-thread cut in jacket and exterior of gun finished except at muzzle.
13. Gun rifled and slotted for breech-block.
14. Parts of breech mechanism finished.
15. Muzzle end of gun cut off and finished.
16. Breech mechanism fitted and bore and rifling smoothed by "lapping."

Following the shrinkage of tube and jacket the main body of the piece was remounted in the turning-lathe six times, was separately mounted, and once turned end for end in the boring bed for finishing the bore and chamber, and was mounted and once turned end for end on the rifling-machine (planer) for the rifling and slotting of the breech-screw. The processes of manufacture naturally fall under two headings, viz, the machining and the shrinkage operations.

MACHINING.

The general rule was adopted to bore and carefully measure all pieces for shrinkage before turning the corresponding surfaces. The prescribed shrinkages being then added, the diameters for the turning were fixed and the gauges adjusted. By this means the errors incident to machining were limited to the single operation of turning, and the *prescribed shrinkages*, which constitute the matter of chief importance, were attained as nearly as practicable. As regards the nature of the finish given to the surfaces, trueness combined with a smooth machine finish was sought, and no polishing material was used on the shrinkage surfaces. Oil was used as a lubricant in boring the jacket, and its interior was left very smooth. The hoops were bored dry, attached by "dogs" to the face plate of lathe, using a single cutting tool. In some cases a finishing file, applied by hand, was used after the tool to true up the bore and remove a very small amount of material. The necessity for this generally arose from the wear of the tool in running through the bore, the effect of this being to leave the bore smallest at the far end, or, if the workman attempted to correct for the wear of the tool, slight inequalities of bore were sometimes produced, which were corrected by the filing. Filing was not resorted to in the finish of the exterior surfaces, because the weight of piece involved in these operations was so great, that sufficient velocity could not be imparted to it with the machinery available. It may be remarked here that polished

shrinkage surfaces are not considered necessary or even expedient. An effective grip between the surfaces is needed to stiffen the gun longitudinally, and the surfaces should in general be finished to that degree of fineness necessary to admit of accurate measurement.

The hoops were the first of the forgings of the gun received. They were fine-bored, and finished to length, except the outer ends of A_{13}, B_{11}, and D_1. The exteriors of all were turned off to a uniform surplus of 0.1 of an inch over the diameters prescribed for the finish, in order to bring them as nearly as practicable to finished dimensions and to make a careful examination for flaws in the metal before the shrinkage. The lap of hoop D_1, however, was not turned down, and that of hoop C_3, was left 0.25 of an inch full until after the shrinkage; the supposition being that if these parts were thinned down before shrinkage they would be eventually less efficacious than by the method adopted. The measurements (see Addenda II, Appendix 18, Report of the Chief of Ordnance, 1886) were made as the hoops were finished, and the pieces then boxed and laid aside until needed.

The counterbore of the jacket at muzzle was finished in a lathe, like the hoops, the bearing being too short for a cutter-head (boring-tool) to do accurate work. As a final test of the bore of jacket, a cast-iron dummy, about 3 feet in length, was turned to fit closely the main bore, the shoulders, and the small bore at bottom. This piece was inserted and the contact of the shoulders tested by smearing with red lead. Templets were afterwards made from this dummy to finish the breech end of the tube. It is deemed important to exercise great care to prevent interference in the insertion of the tube at inaccessible places of this kind; and in any case, if the construction demands a clearance at a shoulder, it is better to make the clearance too much rather than too little. The barrel of the jacket was not turned on the exterior before the shrinkage, because when received it had only about 0.125 of an inch surplus diameter, and this was deemed little enough to protect so heavy a piece in the operations of heating and in handling.

The tube was, in the first instance, rough-chambered and bored to 0.1 of an inch under finished size, and so remained until the whole body of the gun was assembled. The shrinkage surface for the jacket was turned, and also that for the whole C row of hoops. The chase of the tube, which was not to be hooped, was left as full as possible until the last, in order to preserve stiffness. The shrinkage surface for the C row of hoops was turned in the first instance to enable a part of those hoops to be assembled immediately after the jacket, and thus obviate an additional mounting of the piece in the turning-lathe, but it was afterwards found that a mistake had been made, and that the shrinkage surface over this portion of the tube should not have been finished until after the assemblage of the jacket. From some cause not clearly explainable, but supposed to arise from longitudinal strains caused by the grip of the jacket in cooling down, the tube was warped or bent after the jacket was shrunk on. When, after assembling four of the C hoops, the piece was put in the lathe and revolved on the centers of plugs inserted in the breech and the muzzle of the tube it was found to swing out of true, near the muzzle end of the jacket, 0.057 of an inch by measurement, or a bend of about 0.03 of an inch in the length of the tube was indicated. The surplus metal in the bore and in the chase of the tube enabled the muzzle center to be so moved as to correct the defect entirely for that part of the gun, but the finished shrinkage surface on the tube, which extended about 40 inches forward of the hoops already placed, could

not be corrected. However, the inaccuracy there, which resulted in leaving one side of the hoops slightly thicker than the other, was eventually so slight as to be considered of little importance. But had this surface been unfinished the defect could have been entirely corrected. The experience gained has been useful in this respect, and also shows the need of leaving a fair margin of metal in the bore during these operations to provide for such a contingency. One-tenth of an inch is the least that should be allowed in an 8-inch bore, and 0.125 of an inch is recommended. For a larger bore and longer tube a greater margin should be allowed. The piece was placed in a drilling-machine to bore the holes for the coupling-pins, but, owing to carelessness of the workman, it was afterwards found necessary to ream them out with a hand-drill, since it was essential that they should be made exceedingly smooth and true to fulfill the object of their use.

In all cases of finishing the rounds and fillets at shoulders the machinery was done to gauges which had been previously prepared and fitted to correspond and give the prescribed clearances. In preparing the lap for hoop A_1 over the shoulder of jacket and a portion of hoop D_1, the length of the lap was made 0.005 of an inch shorter than the distance between the shoulder of the hoop (A_1) and its front face. This was done in order to insure a bearing at the shoulder within the hoop. For the lap of hoop C_4 on C_{3a} the two lengths were made identical, and a close outside joint was obtained.

The trunnion hoop was finished completely before shrinkage.

It may be noted that in fine-boring the tube, the length of bore being nearly 192 inches, the bore was true to size for about 166 inches; it then gradually and uniformly increased, in conical form, for some 26 inches to the forward end of chamber. The maximum increase amounted to 0.007 of an inch. The wear of the tool, which, in order to make a very fine finish, was not removed during the operation, should have caused the reverse of what occurred. The best explanation offered to account for the enlargement is, that as the chips were pushed forward into the chamber and confined there they crowded the head as it approached the bottom of the bore and caused it to spread. This, of course, might have been provided against, but it is given as a new and somewhat remarkable experience.

The rifling bar was made for the contractors at the Washington navy-yard, District of Columbia; it is about 6.5 inches in diameter, and has upon it, besides the single groove used for this gun, two grooves, adapted for cutting the cuniform grooves of the 8-inch navy guns which were being made at the same time at these works. The rifling-head received with the bar was made of steel, and the cutters narrow tools, which necessitated a circular moving feed to cut the width of each groove. The head holds two cutting tools, set at a distance apart, adapted to cut two grooves at one time. After commencing work with the steel head some difficulty was found from scoring by reason of the chips getting between the moving head and the surface of the bore, and finally the head stuck fast from the same cause. The exterior of the head was then turned off and the steel surface replaced by a bronze sleeve, with the result that although the head was scored and wore away more rapidly than the steel would have done, yet the harder surface of the steel bore was less liable to be injured. At this time, also, additional precautions were taken to remove all the steel chips from the bore between each passage of the rifling-head and to lubricate plentifully with oil.

The rifling was operated as follows: The gun was fixed in bearings in line with the center of a planing machine. The breech of the gun

was clamped in a collar, and there was attached a toothed index-wheel and clutch suited to set the gun for cutting each individual groove, and the piece was revolved at the proper time, for this purpose only, by a worm and gear-wheel attached near the breech. The rifling bar was supported by two standards and bearings in which it could revolve, but was held longitudinally by the rear one, which was attached to the table and communicated the forward and back traveling motion to the bar. The front support of the bar was placed about 15 inches from the muzzle of the gun. This standard was fixed in position and the table moved beneath it. The bar was supported in a bushing having a stud on which the groove in the rifling bar traveled and communicated the rifling motion. Connected with this bushing was an arm which extended downward and the extremity of which was held between two adjustable clamp-screws. And by means of these screws the feed of the cutting tool necessary to cut the width of each individual groove was regulated. The machine was stopped each time the bar was withdrawn and the chips cleaned by passing (by hand) swabs through from the breech end. The first was a rubber disk screwed to the head of a long wooden rod; when this was passed through to the muzzle, removing the greater portion of the chips, the head was unscrewed and the rod withdrawn alone to the rear. The second swab was a large sponge, well oiled, and when this was passed through the adhering chips were removed by men stationed at the muzzle before the swab was drawn back. To complete the lubrication oil was frequently injected from the breech into the bore by a large syringe, following the retreat of the rifling head. Considerable difficulty was found in making cutting tools which would stand the work, and in one instance the cutting edge and a part of one tool was sheared off, and remained embedded in the gun. To obviate a defective land it then became necessary to make a slight change in the width of the lands and grooves remaining to be cut, but the parallelism of the edges was preserved.

The "lapping" head for the rifled bore was a solid cylinder of lead about 8 inches long, cast in a mold to fit the rifling; it was attached to the end of an iron rod and operated by four men. Fine emery and oil was used for polishing. Notwithstanding a great amount of labor expended in this way—except to smooth down the edges of the lands and the sides of the grooves—slight tool marks in the bottom of the grooves, perceptible in the shades of light, but sometimes more marked, could not be removed. The chamber was so smoothly finished that no lapping was necessary, but as a precautionary measure the slopes were polished with solid wooden forms and emery and oil. Measurements of the finished bore and rifling are given in Addenda V of the Inspection Report. (See Appendix 18, Report of the Chief of Ordnance, 1886.)

Work on various parts of the breech mechanism was done from time to time as the remainder progressed, but the thread on the block was not cut until after the screw in the jacket. In threading the block the commendable caution was taken, at the instance of the superintendent of the works, to mount it upon a long mandrel in the same lathe and the same position; also to finish the thread in the same direction as in the case of the breech-screw. By this means it was sought, and also no doubt accomplished, to make the two threads bear very evenly when brought under strained contact in the firing. Great care was necessarily exercised in finishing and fitting the various parts of the breech mechanism, and only the most experienced workmen were employed; and, respecting this, it may be remarked that the best workmen at the West Point Foundry are notably proficient. No special difficulty was found

in machining the block, and its construction, with solidly attached handles, certainly affords obvious advantages in simplicity and strength over one requiring a face-plate.

THE SHRINKAGE OPERATIONS.

When this gun was undertaken the West Point Foundry had no provisions made for heating the parts for shrinkage. Shortly before this some experimental work of the kind had been done on two occasions; in the first the hoops were heated by a wood fire built around them in the yard, but the heating was found to be unequal and so little under control that on the second occasion the hoops were heated as far as was practicable with means at hand in a medium of hot air with very satisfactory results. Meantime, at the South Boston Foundry a gas-heating apparatus had been used for this purpose, and was found to be economical of fuel and to possess marked conveniences for the work. There is little doubt that had the West Point Foundry been provided with gas at this time the method used at South Boston would have been adopted. On the question of merit for heating purposes, having due regard to uniformity and purity of the heating elements, the hot air was considered best, and estimates of cost showed that there would be little difference in the matter of economy. It was therefore decided by the contractors to construct a special furnace for heating by means of hot air. This course had been previously suggested and advocated by the inspector, and the principles involved met with his full approval. The furnace which was built served its purpose quite well, but was deficient in appliances for handling the pieces of metal to be heated, and no special apparatus was provided for transferring the heated piece in an easy and safe manner from the hot-air chamber to its place on the gun. This transferring was all done by block and fall, or cranes, in connection with bands of wrought-iron provided with eye-rings which were clamped around the piece before the heating and removed when the piece was in position on the gun.

The hot-air chamber of the furnace was formed by a cast-iron cylinder about 4½ feet in diameter by 12 feet long; it was laid horizontally, with its lower side about 5 feet above the floor with which the ash-pit ran level. The cylinder was jointed, having been cast in several sections with outside flanges that were embedded in the wall of the brick casing surrounding the whole. Underneath the cylinder a false bottom of semicircular form was fixed to leave an air-space some 6 inches deep; this bottom was interposed between the fire-box and the cylinder so that the flame did not come in contact with the latter on its under side. The fire-box and grate extended the whole length of the structure below. The ash-pit and grate were made about 20 inches wide and the fire-box built up of ordinary brick laid in horizontal courses flared outwards from the grate to meet the walls of the casing about the level of the false bottom. Coal was used as fuel. The flame rose around the sides of the cylinder and the smoke ascended through a pipe stack, the base of which rested on the top of the brick structure at the middle length, near one side. Cold-air ducts into the air-space were provided, but were little, if at all, used. A couple of apertures were made at the top of the chamber for the purpose of ventilation and for the insertion of thermometers. When not used for temperature observations these apertures were kept nearly closed. The front end of the chamber was closed or entirely opened by means of a pair of close-fitting iron doors, and through one of them a third opening, for observations of temperature, &c., was made. This opening was habitually kept closed.

The pieces were passed in and out of the heating chamber on an iron car, which was built with special reference to heating the jacket, but was used also for the hoops, which were laid loosely on it. The number of hoops heated at one time varied from one to three, depending upon convenience of work. Outside and in front of the furnace a common platform car (short) was placed on rails to raise the top of it to a level with the bottom of the chamber. This car could be run back enough to clear the doors of the chamber for opening and to bring the pieces on the iron car within reach of the shop crane. The iron car was run on rails laid on the top of the platform car, and rails were laid on the bottom of the chamber in prolongation of these, so that when the doors were opened and the platform car run in, the iron car passed readily into the chamber. The supports for the jacket, which was laid in a horizontal position on the iron car, consisted of V-shaped transoms, 18 inches apart. The line of support was made straight and true by machining the tops of the transoms in a planer.

The air in the chamber could be raised to a temperature of about 500° F. in from three to four hours after starting the fire, and the heat once acquired but little fuel was required to maintain it. Taking a case where the temperature was raised at times to about 750° F., the amount of coal consumed in starting the fire and maintaining it for thirty hours was about 3,000 pounds. The maximum temperature to which the air could be raised was found to be about 800° F. A high-registering mercurial thermometer was used at first in one of the top openings, but was broken by the heat. The temperature was gauged from time to time by a hydro-pyrometer, the copper piece being inserted through the opening in the door to the level of the piece which was being heated. The best determinations of temperature confirmed closely the rule that within the limits of temperature usually employed in gun construction, a diametrical expansion of 0.00139 of an inch per linear inch corresponds to 212° F. elevation of temperature, or that the expansion is 0.0000065534 of an inch per linear inch for each degree Fahrenheit elevation. This rule may be expressed as follows: Let D represent the original, D_1 the expanded diameter, and $D_1 - D = a$ the absolute expansion; call t the temperature of the outside air and d the expansion per linear unit,

then $$d = \frac{a}{D}$$

and the temperature of the metal in Fahrenheit degrees will be given by

$$T = \frac{d}{0.0000065534} + t.$$

The temperatures recorded in the Inspection Report, Addenda IV, Appendix 18, Report of the Chief of Ordnance, 1886, were determined by this rule. Referring to that we note that in some cases the temperatures were unnecessarily high. For the jacket (740 degrees) it was proper to be assured of a good degree of heat on account of the weight of the piece and possible delays in the assemblage, but owing to inadequacy or lack of preparation several of the hoops were left an unncessary length of time in the furnace. The least recorded temperature of hoop was that of C_4, 450 degrees, and the highest A_2, 815 degrees. As a general rule a *clearance* of from 0.03 to 0.035 of an inch would suffice for the assemblage, and the corresponding temperature would be from 500 to 550 degrees Fahrenheit.

Gauge-disks for the different bores of the jacket, mounted on iron rods, and gauge-rods for the hoops were set in advance of the heating

to test the expansion from time to time and determine the proper time for withdrawal. After some experience, by observing the heat of the furnace and the length of time after insertion, it was not difficult to judge, without the use of temperature determinations or gauges, when the hoops had reached the proper degree of expansion or heat. And it was shown that, with a proper system, which it would be easy to manage, a minimum of labor and anxiety can be had in the use of hot air for heating purposes. By fixing proper intervals between the insertions a furnace with a capacity for 2, or at most 3 hoops, would enable any number to be assembled without delays for heating.

The length expansion of the jacket was measured when the temperature of metal was about 725 degrees Fahrenheit, by means of a templet extending the length (87.36 inches) of the bore. The expansion in the length was found to be 0.38 of an inch. This was very nearly what was to be anticipated from the temperature, applying the preceding rule for expansions, but it is important to note the magnitude of this length expansion, which also measures approximately the contraction in the length of the jacket in cooling down under shrinkage. After the shrinkage the permanent set in the length of this jacket was found to be 0.03 of an inch; its actual contraction in cooling was then 0.35 of an inch. This makes it a matter of considerable importance that in such long shrinkage surfaces the boring and turning should be very true, since if the outer cylinder should clamp tangentially at certain points whilst still unduly extended in length, dangerous and unequal strains would probably be introduced. Moreover, whilst very smooth finish for such surfaces is not advocated in general, yet, if we wished to introduce here a relatively rough surface for the prevention of ulterior longitudinal slipping, we would necessarily confine such a surface to a few inches towards the end where the outside cylinder is (as is general) artificially cooled with water.

The tube and jacket were assembled by lowering the tube into the heated jacket, which rested, breech down, over a centering plug fixed in the bottom of the shrinkage pit. Preparatory to this the tube had been suspended by the muzzle vertically above the center of the pit, and was raised so as to clear the way for the transfer of the heated jacket from the furnace to the pit. The muzzle of the jacket projected about 15 inches above the mouth of the pit, and was "stayed" in a vertical position; its transfer from the furnace to this position was effected in a little less than 5 minutes, and the tube was then lowered into the jacket in 1 minute. A circular sprinkler throwing fine jets of water was quickly placed around the muzzle end of the jacket to cool it and cause it to clamp first at that part. The shoulder of the tube came squarely down upon the muzzle face of the jacket, and showed no opening there, but after a time a slight opening appeared, and ultimately this joint was irregular, and gave an opening at one place equal to 0.028 of an inch. One principal objection to be made to this mode of insertion is the difficulty of proper water-cooling. A tin collar forming a water-shed was fixed below the sprinkler, and the jacket was also wrapped with strands of rope, yet streams of water could not be prevented from running down the sides. It was due to this perhaps in part, in connection with abnormal longitudinal strains, that the warping of the tube before mentioned occurred. At all events, the rational method of cooling would require that the jacket should be uppermost in the assemblage, for in this position the cooling could be made even all around and the application of water limited to exactly the part desired to be cooled.

The jacket was 9 hours and 21 minutes in the furnace. It had been placed there at midnight, and at 7.30 a. m. the gauge-disks entered freely, but an unexpected delay then occurred in removing it to make some change in the preparations. It was finally taken out at 9.22 a. m. The cooling with water proceeded gradually from the muzzle towards the breech, and the whole operation was completed about noon. During the assemblage and cooling the bore of the tube was kept filled with cold water supplied by connecting pipes.

This cold-water supply in the bore was also kept up during the assemblage of the hoops. It was arranged as follows: Both ends of the tube were closed and a discharge-pipe of 1.5-inch bore and some inches shorter in length than the bore of gun was fixed through one of the head-plates. A 2.5-inch hose conducted the water to the pipe, and the outlet pipe, 2-inches in diameter, was fixed at the same end, so that the water was discharged at the far end and circulated through the length of the bore.

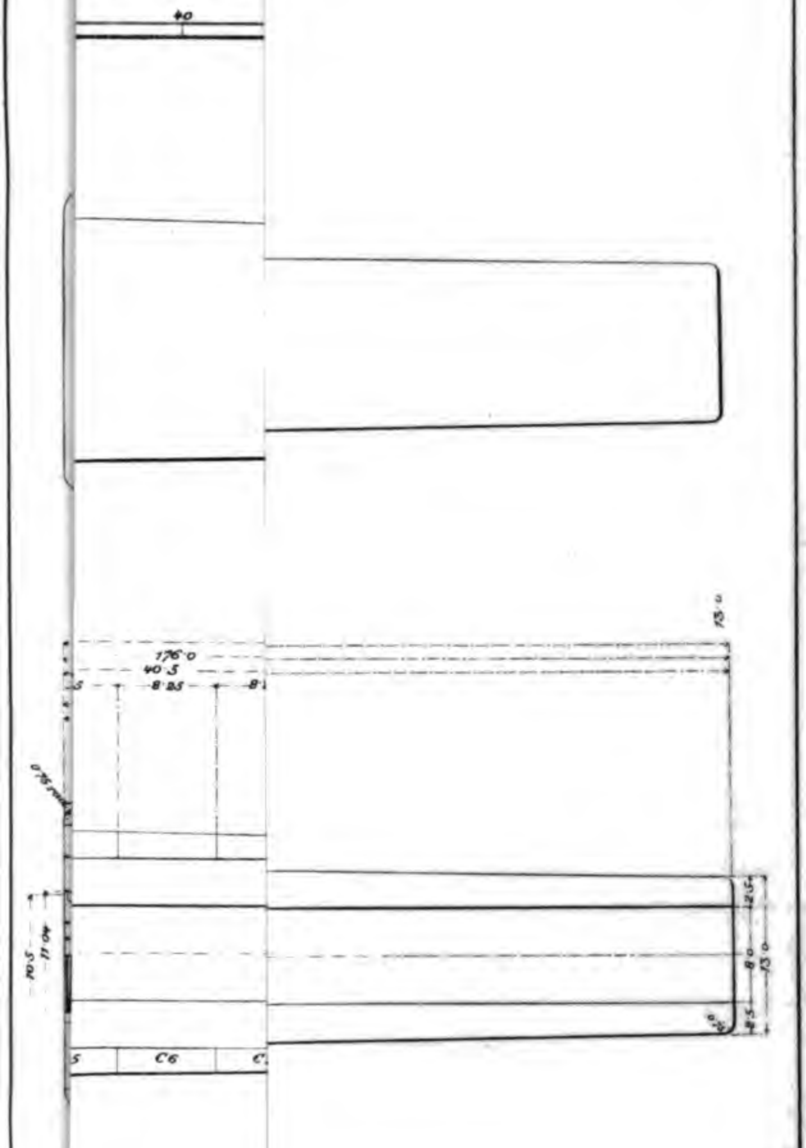
The circular sprinkler which was used for the progressive outside cooling of all the pieces consisted of two circular-bent arms made of 1-inch iron pipe; they were closed at the outer ends and connected with the supply pipe at the other ends by ball-and-socket joints. Numerous holes were made on the inside of the arcs to discharge the water in small jets. The arms, or arcs, were made of various sizes to encircle the outside of the piece which required cooling.

The apparatus used for applying pressure to hold the hoops up to place whilst they were being cooled was more remarkable for its cheapness than its efficacy, and the greater credit for the results obtained in making close joints was due to the careful use of the water-sprinklers. The apparatus consisted of a section of heavy sheet-iron pipe, 1 to 15 inches larger interior diameter than the zone of gun to be hooped, and of sufficient length to reach from the hoop in position to a distance beyond the extremity of the gun over which the hoop was assembled. An iron rod was passed through the bore of the gun and secured by head and nuts to the water-tight end-plates at the two extremities; this rod also projected from the gun to a greater distance than the pipe, and was threaded over this projection. In the assemblage the gun was laid horizontally, and the hoop supported by the crane was slipped over the end of gun and pushed along by hand labor with the swing of the crane to its position. The pipe was then passed on to abut against the outside face of the hoop; it was supported at the rear end by a follower—a plate of sufficient size to cover the end—and the pressure was applied by means of a large nut working on the threaded portion of the projecting rod against the follower. This latter piece was made in two parts, hinged together, to obviate the necessity of removing the nut from the rod. The various pieces of pipe were faced true at the ends before being used.

Good joints between the hoops were secured in most instances, and all were fairly good. In many places the contact was apparently perfect, and the average opening measured about 0.004 of an inch. The maximum opening between any two hoops was 0.013 of an inch. The width of these openings was measured by inserting thin sheets of brass or tin which were pushed to the bottom, that is, through the thickness of the hoop to the surface under the joint. The differences in width of joint at different depths were seldom perceptible. More or less irregularity was found in the width of joints observed individually; they were generally closest at top, as the gun lay, and it is believed that this arose at least in part from the position. In cooling the hoop with

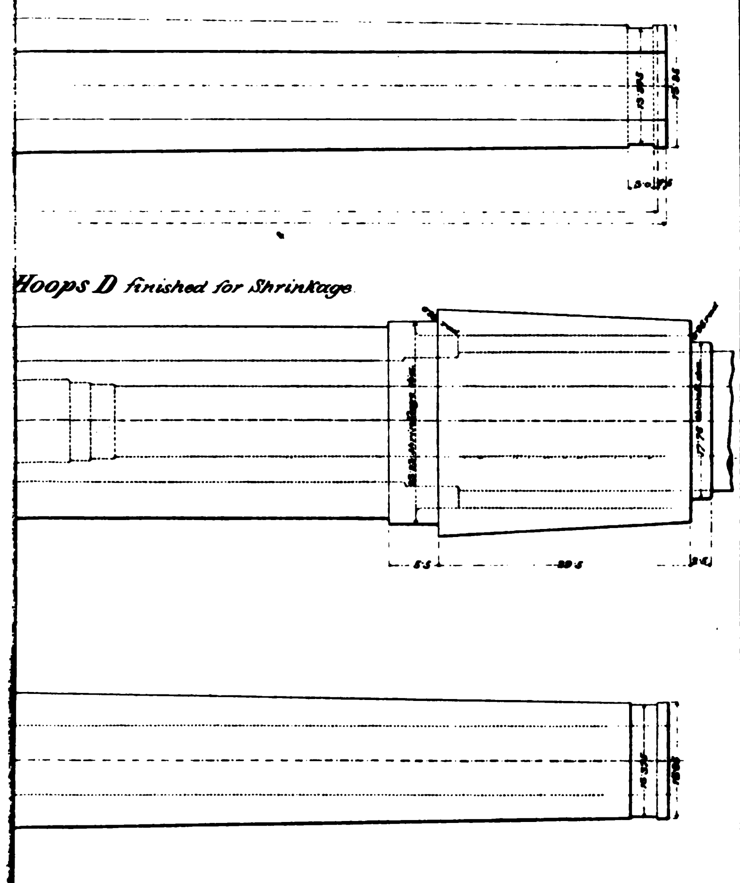
the gun in a horizontal position streams of water would run in various directions, and the cooling could not be confined as desired. This and other considerations, to which my attention was first called by General Henry L. Abbot, United States Engineers, lead to the conclusion that the gun should be placed in a vertical position for the hooping. In substance it was remarked that the hoop, when brought to position, would rest only on its top element, that it would be in a disadvantageous position to contract uniformily and evenly on the under cylinder, and this disadvantage would be aggravated in the case of large and heavy hoops or cylinders, possibly heated to a degree that would cause deformation when suspended in this position.

STEEL, 13



Appendix 17—1886.

H E


Hoops D finished for Shrinkage

APPENDIX 18.

INSPECTION REPORT OF EXPERIMENTAL STEEL, 8-INCH BREECH-LOADING RIFLE No. 1.

BY CAPT. ROGERS BIRNIE, JR., ORDNANCE DEPARTMENT.

OFFICE OF INSPECTOR OF ORDNANCE, U. S. A.,
WEST POINT FOUNDRY,
Cold Spring, N. Y., July 10, 1886.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.:

GENERAL: I have the honor to transmit herewith inspection report, with five addenda, of experimental, steel, 8 inch breech-loading rifle No. 1, made at this foundry under contract with Messrs. Paulding, Kemble & Co., dated June 23, 1884.

Very respectfully, your obedient servant,

R. BIRNIE, JR.,
Lieutenant of Ordnance.

Report of inspection of experimental, steel, 8-inch breech-loading rifle No. 1, *manufactured at the West Point Foundry, under contract of Chief of Ordnance, U. S. Army, dated June* 23, 1884.

Subject of measurement.	Dimensions.		Actual variations.	Remarks.
	Prescribed.	Actual.		
	Inches.	*Inches.*	*Inches.*	
Diameter of bore across lands	8.00	8.00	−0.001 +0.007	Variation +0.007 at front of shot chamber, thence contracts uniformly to zero in 26 inches forward.
Diameter of shot chamber	8.19	8.20	+0.005 +0.014	Irregularly bored.
Diameter of powder chamber	9.50	9.499	−0.002 −0.001	
Number of grooves and lands	45.00	45.00	....	Pitch of rifling verified on rifling bar, increasing from 1 turn in 70 calibers at origin to 1 in 25 at 16 inches from muzzle, thence uniform, 1 in 25, to muzzle.
Width of lands	0.17	0.17	− 0.035	
Width of grooves	0.3884	0.3884	+0.015	
Depth of grooves	0.06	0.0615	−0.002 +0.005	
Grooves filleted, with radius of	0.08	0.08	....	Principal cause of varying width of grooves and lands due to score made in bore by breaking of rifling tool. Position of some grooves changed to cut out this score. Besides this defect, the grooves show tool-marks or scores at bottom in several places, which could not be removed by long-continued "lapping" or grinding.
Lands rounded, with radius of	0.01	0.01	....	
Length of rifled bore	191.36	191.51	+0.15	
Length of shot-chamber slope	1.25	1.25	....	
Length of shot chamber	3.14	3.14	....	
Length of powder chamber and slope	49.75	49.75	....	
Total length of bore of tube (and of tube)	245.50	245.65	+0.15	

Report of inspection of experimental, steel, 8-inch breech-loading rifle No. 1, &c.—**Cont'd.**

Subject of measurement.	Dimensions. Prescribed.	Dimensions. Actual.	Actual variations.	Remarks.
	Inches.	*Inches.*	*Inches.*	
Length of bore in front of obturator, breech closed.	239.975	240.125	+0.15	Effective length of bore = 30 calibers.
Diameter of breech-recess in slots	11.06	11.06		
Diameter of breech-recess to bottom of threads	11.04	11.04		
Diameter of breech-block to top of threads	11.00	11.00		
Diameter of breech-recess to top of threads	10.50	10.50		
Diameter of breech-block to bottom of threads	10.46	10.46		
Diameter of breech-block in slots	10.42	10.42		
Number of smooth and threaded sectors	3.00	3.00		
Length of breech-recess	12.50	12.56	+0.06	Insertion of tube in jacket left an open joint 0.107 of an inch at front end of breech-recess; this was afterward caulked with copper.
Length of breech-block, including handles	16.90	16.90		
Length of threaded portion of breech-recess	11.00	11.00		
Length of threaded portion of breech-block	11.75	11.75		
Pitch of thread in recess and on block	0.75	0.75		
Maximum diameter of head of obturator-stem	9.45	9.455	+0.005	
Diameter of axial vent through stem	0.2	0.2		
Diameter of vent through copper bushing	0.1	0.1		
Diameters over tube:				
Breech to first shoulder, within jacket (length 4".5).	13.05	13.043	—0.007	Jacket coupled to tube (longitudinally) by 4 steel pins 2 inches diameter, 90° apart, passed through wall of jacket in front of shoulder and let into tube 0.375 of an inch—closely fitted and secured each by a screw cap.
First to second shoulder, within jacket (length 76".75).	14.05	14.05		
Second to third shoulder, within jacket (length 6".2).	14.60	14.598	—0.002	
Third shoulder to chase, under C row (length 67".14).	15.75	15.749	—0.001	
Diameters over jacket:				
Breech to shoulder, under A row (length 91".50).	22.00	22.00		
Shoulder, under A row (length 3".0)	23.20	23.197	—0.003	
Shoulder to muzzle end, under D row (length 5".36).	19.80	19.799	—0.001	
Total length of jacket	99.86	99.86		
Diameter of A row of hoops, under B row	26.30	26.299	—0.001	Actually, interior diameter of B row.
Length of A row, 12 hoops	97.00	97.00		
Diameter of C row of hoops, under D row	19.80	19.799	—0.001	Actually, interior diameter of D row.
Length of C row, 9 hoops	67.14	67.14		
Length of D row, 3 hoops	32.00	32.00		
Length of B row, 10 hoops	85.50	85.50		
Exterior diameters of gun:				
Reinforce	31.50	31.50		
Trunnion-hoop	32.76	32.77	+0.01	
Base of third chase slope	30.00	30.00		
Base of second chase slope	25.80	25.80		
Base of first chase slope	20.75	20.75		
Base of chase	15.75	15.765	+0.015	
Muzzle of gun	13.00	13.00		
Diameter of trunnions	10.00	9.996	—0.004	
Distance between rim-bases	34.00	34.00		
Length of trunnions	6.00	6.00		
Length of gun, axis of trunnions to breech	82.00	81.96	—0.04	
Length of gun, axis of trunnions to muzzle	176.00	176.25	+0.25	
Length of chase of gun, unhooped	91.00	91.09	+0.09	
Total length of gun over all, breech closed	271.50	271.71	+0.21	

	Pounds.
Weight of breech-block, obturator, and lever complete	434
Weight of body of gun, without fixtures	28,960
Weight of gun complete	29,544
Breech preponderance, axis of gun horizontal	204

Preponderance equals weight on scales under support placed 58 inches in rear of axis of trunnions.

Physical properties.

[From tests of specimens taken tangentially by tension.]

Specimens taken from—	Area of cross-section.	Density.	Tenacity.	Hardness.	Elastic limit.	Elongation per inch at rupture.	Remarks.
Tube:							
Breech end	0.25	....	82880.	....	35000.	20.16	Whitworth steel, 3-inch specimens.
Muzzle end	0.25	7.8521	99790.	....	53330.	23.86	Whitworth steel, 2-inch specimens.
Jacket, breech end.	0.25	7.8661	93780.	20.3	52500.	21.00	Whitworth steel, 3-inch specimens.
Trunnion hoop	0.25	7.8665	86090.	16.91	36330.	17.39	Whitworth steel, 6-inch specimens.
Plain hoops*	0.25	7.8580	113880.	24.78	63170.	12.30	C and D rows, Midvale steel
		7.8603	107390.	24.79	61750.	13.94	A and B rows, Midvale steel.

*6-inch specimens only recorded here.

The following addenda accompany this report, viz:

I.—Summary of tests of metals.
II.—Measurements of hoops prepared for shrinkage.
III.—Statement of shrinkages employed and resulting compressions of bore.
IV.—Summary of the shrinkage operations; heating, expansions, temperatures, &c.
V.—Measurements of finished bore and rifling.

I certify that the foregoing report is correct, and that the 8-inch rifle therein specified has been accepted by me as conforming to the standards as to dimensions, quality of material, and character of workmanship prescribed by the Ordnance Department.

June 26, 1886.

R. BIRNIE, JR.,
Lieutenant of Ordnance, Inspector.

ADDENDA I.

Inspection report of experimental, steel, breech-loading rifle No. 1, manufactured at West Point Foundry.

RECORD OF TESTS OF METALS.

Mean results of tests on bars, taken tangentially.

Tube forging: Whitworth steel.]

Subject of measurement.	By tension.		By compression, breech-end.	Remarks.
	Breech-end.	Muzzle-end.		
Number of specimens tested	2.	3.	3.	The fracture of specimens from breech showed, under tension, a granular surface, also in one specimen an indication of a seam, and in the other, fine cracks on the bar after fracture; under compression the three specimens showed a rapid deflection after passing the elastic limit. Tests of two crushing specimen-cylinders 3''.005 long by 0''.7965 diameter, taken from the breech, gave the following results: Specimens loaded with 150,000 pounds pressure per square inch, distortion took place by deflection laterally and sides swelling; length of specimens after test, 1''.68 and 1''.65 respectively. The fracture of specimens from muzzle all showed a silky surface, except one which was 60 per cent. granular. The manufacturer, Sir J. Whitworth & Co., reported the following tests of this metal on specimens, 2''.0 length between shoulders, taken longitudinally, viz: Elastic limit, 27.8 tons per square inch; tensile strength, 46.3 tons per square inch; ultimate elongation, 16.5 per cent. The values used to represent the elastic properties of the tube-metal in computing the shrinkages for the construction of the gun were as follows: Elastic limit, 49,600 pounds, or 22.143 tons per square inch; elastic displacement, 1.6 thousandths per linear inch; modulus of elasticity, 31,001,600 pounds, or 13,840 tons. These approach more nearly the physical characteristics of the muzzle end. They were used principally because the shrinkages for the gun had already been computed for a different tube, but it was believed that the qualities shown by the tests from muzzle warranted their use with this tube, and the successive compressions of bore of gun measured during its manufacture indicate the approximate correctness of the assumption made.
Diameter of specimen bars ... inches	0.564	0.564	0.798	
Length of specimen bars ... do	3.00	2.00	5.00	
Load per square inch of cross-section (pounds).	Elongations or compressions per inch (thousandths).			
10,000	0.25	0.15	0.292	
15,000	0.40	0.267	0.442	
20,000	0.60	0.40	0.575	
25,000	0.816	0.517	0.75	
30,000	1.033	0.683	0.958	
35,000	1.667	0.85	1.408	
40,000	5.20	1.033	5.775	
45,000	8.833	1.233	9.816	
50,000	13.917	1.40		
55,000	....	3.767	....	
60,000	25.80	9.583	....	
70,000	46.70	17.55	....	
78,000	88.35	26.40	....	
Elastic limit ... pounds per square inch .. minimum	33,000.	49,000.	34,000.	
maximum	37,000.	58,000.	36,000.	
average	35,000.	53,330.	35,000.	
Corresponding elongations ... thousandths .. minimum	1.3	1.3	1.125	
maximum	1.4	1.65	1.3	
average	1.35	1.517	1.242	

Resistance at failure, on primitive section, pounds per square inch	minimum	78, 880.	97, 200.	....
	maximum	86, 880.	101, 920.	....
	average	82, 8[illegible]0.	99, 790.	....
Elongation per inch, after rupture ... per cent.	minimum	19.	20.	....
	maximum	21. 33	27. 5	....
	average	20 16	23. 86	....
Area of primitive section ... square inches		0. 25	0. 25	1.
Reduction of area after rupture, per cent. of primitive section	minimum	30. 6	36. 4	....
	maximum	36. 4	41. 9	....
	average	33. 5	40.	....
Specific gravity		....	7. 8521	....
Hardness		....	....	....

Mean results of tests of bars taken from breech end.

[Jacket forging: Whitworth steel.]

Subject of measurement.	By tension. Tangential specimens.	By tension. Longitudinal specimens.	By compression. Tangential specimens.	By compression. Radial specimens.	Remarks.
Number of specimens tested	2	3	2	2	Undertension,the fr ture of the two t gential specim showed one fine gr ulation with d center and one sil and the three lon tudinal specimens silky except one terspersed with t granulation.
Diameter of specimen bar, inches	0.564	0.564	0.798	0.798	
Length of specimen bar, inches	3	2	5	5	
Load per square inch of cross-section (pounds).	**Elongations or compression per inch (thousandths).**				
15,000	0.433	0.383	0.517	0.50	
30,000	0.950	0.950	1.017	0.983	
35,000	1.10	1.10	1.167	1.15	
40,000	1.25	1.267	1.333	1.30	
45,000	1.40	1.45	1.50	1.467	Under compression, of the four specime failed by triple fl ure.
46,000	1.45	1.50	1.984	3.533	
47,000	1.50	1.516	2.583	3.717	
48,000	1.566	1.55	3.433	4.05	
49,000	1.788	4.767	4.217	4.283	
50,000	6.95	5.016	4.517	7.567	
55,000	9.084	9.667	6.133	11.40	
60,000	15.25	13.116			
66,000	21.684	20.216			
72,000	30.083	28.733			
80,000	50.333	46.716			
Elastic limit, pounds per square inch.. Min..	48,000	48,000	45,000	45,000	
Elastic limit, pounds per square inch.. Max.	57,000	61,000	56,000	49,000	
Elastic limit, pounds per square inch.. Aver.	52,500	53,000	50,500	47,000	
Corresponding elongation or compression, thousandths Min..	1.6	1.55	1.567	1.433	
Corresponding elongation or compression, thousandths Max.	1.867	2.00	1.767	1.633	
Corresponding elongation or compression, thousandths Aver.	1.734	1.717	1.667	1.533	
Resistance at failure on primitive section, pounds per square inch .... Min..	84,360	85,480	79,000	81,520	
Resistance at failure on primitive section, pounds per square inch .... Max	103,200	106,800	87,280	88,640	
Resistance at failure on primitive section, pounds per square inch .... Aver	93,780	94,080	83,140	85,080	
Elongation per inch after rupture, per cent Min..	17.67	22.0			
Elongation per inch after rupture, per cent Max.	24.33	29.5			
Elongation per inch after rupture, per cent Aver.	21.00	23.0			
Area of primitive section, square inches	0.25	0.25	0.50	0.50	
Reduction of area after rupture, per cent. of primitive section Min..	36.4	47.2			
Reduction of area after rupture, per cent. of primitive section Max	41.9	54.6			
Reduction of area after rupture, per cent. of primitive section Aver.	39.2	51.3			
Specific gravity	7.8661	7.8641			
Hardness	20.3	14.06			

The values adopted from the results of tests as above to represent the elastic properties of t metal in computing the shrinkages for the construction of the gun were as follows:

Elastic limit, 44,800 pounds, or 20 tons per square inch.
Elastic displacement, 1.44[illegible] thousandths per linear inch.
Modulus of elasticity 31,001,600 pounds, or 13,840 tons.

Mean results of tests of bars taken tangentially.

[Hammered and rolled hoops: Midvale steel.]

Subject of measurement.		Hammered hoops. By tension.		Hammered hoops. By compression.	Rolled hoops. By tension.		Rolled hoops. By compression.
Number of specimens tested		2	6	2	8	16	4
Diameter of specimen bars..inches.		0.564	0.564	1.132	0.564	0.564	1.129
Length of specimen bars.......do..		3.0	6.0	9.0	3.0	6.0	9.0
		Elongations or compressions per inch (thousandths).					
Lead per sq. inch of cross-section:							
15,000 pounds		0.433	0.436	0.433	0.35	0.43	0.416
30,000 pounds		0.931	0.903	0.908	0.825	0.894	0 892
40,000 pounds		1.216	1.225	1.308	1.142	1.226	1.208
45,000 pounds		1.367	1.372	1.586	1 396	1.377	1.883
50,000 pounds		1.50	1.552	1.684	1.487	1.546	1.564
55,000 pounds		1.65	1.714	1.85	1.671	1.715	1.704
56,000 pounds		1.733	1.762	1.87	1.725	1.761	1.729
60,000 pounds		1.867	1.919	1.983	2.096	1.984	1.875
65,000 pounds		2.10	2.716	4.275	3.504	3.013	2.237
70,000 pounds		4.633	5.114	....	6.979	6.067	....
75,000 pounds		8.15	8.667	....	11.075	10.170	....
Elastic limit, pounds per sq. inch	Minimum	65000	59000	60000	54000	55000	58000
	Maximum	65000	67000	60000	70000	67000	65000
	Average	65000	63170	60000	62250	61750	61750
Corresponding elongations or compressions, thousandths	Minimum	2.033	1.883	1.967	1.70	1.70	1.833
	Maximum	2.167	2.116	2.10	2.30	2.15	2.05
	Average	2.10	2.022	2.033	1.975	1.974	1.946
Resistance at failure on primitive section, pounds per sq. inch	Minimum	114480	109800	....	100000	101840	....
	Maximum	116560	117400	....	111160	114000	....
	Average	115520	113880	....	105730	107390	....
Elongation per inch after rupture, per cent	Minimum	15.70	10.00	....	15.00	10.30	....
	Maximum	16.70	14.30	....	19.33	16.67	....
	Average	16.20	12.30	....	17.88	13.94	....
Area of primitive section, sq. inches.		0.25	0 25	1.007	0.25	0.25	1.00
Reduction of area after rupture, per cent. of primitive section.	Minimum	33.60	36.40	....	39.20	27.60	....
	Maximum	39.20	39.20	....	52.20	56.80	....
	Average	36.40	37.80	....	42.50	42.90	....
Specific gravity		....	7.858	....	....	7.8603	....
Hardness		....	24.78	....	....	24.79	....

The values adopted from the results of tests, as above, to represent the elastic properties of these metals in computing the shrinkage for the construction of the gun were as follows:

Hammered hoops.	Used as under row in double hooping.	Elastic limit, 52.640 pounds or 23.5 tons per square inch. Elastic displacement, 1.645 thousandths per linear inch.
	Used as single row directly over tube.	Elastic limit, 51,520 pounds or 23.0 tons per square inch. Elastic displacement, 1.61 thousandths per linear inch.
	Used as outer row in double hooping.	Elastic limit, 48,832 pounds or 21.8 tons per square inch. Elastic displacement, 1.526 thousandths per linear inch.
Rolled hoops.	Used in under row in double hooping.	Elastic limit, 54,390 pounds or 24.28 tons per square inch. Elastic displacement, 1.70 thousandths per linear inch.
	Used as outer row in double hooping.	Elastic limit, 50,000 pounds or 22.32 tons per square inch. Elastic displacement, 1.5625 thousandths per linear inch
	Special for hoop A, used in outer row.	Elastic limit, 51,520 pounds or 23.0 tons per square inch. Elastic displacement, 1.61 thousandths per linear inch.

Modulus of elasticity (common to all), 32,000,064 pounds or 14,286 tons.

Mean results of tests, by tension, on bars taken from—

[Trunnion hoop: Whitworth steel. Coupling-pin bar: Midvale steel. Console: West Point Foundry casting, Cu., 55; Zn., 44.5; Sn., 0.5.]

Subject of measurement.		Trunnion hoop.	Coupling-pin bar.	Console.
Number of specimens tested		3	1	1
Diameter of specimen bar ......inches		0.564	0.564	0.564
Length of specimen bar ......do		6.0	3.0	3.0
Load per square inch of cross-section (pounds).		Elongations per inch (thousandths).		
10,000		0.255	0.233	0.667
15,000		0.405	0.400	1.200
20,000		0.555	0.533	2.067
25,000		0.789	0.733	3.433
30,000		1.144	0.900	7.167
35,000		1.627	1.067	14.933
40,000		2.789	1.233	27.333
45,000		4.416	1.367	42.500
50,000		7.789	1.600	64.067
60,000		17.383	2.033	126.700
66,000		26.388	2.167	......
76,000		66.017	4.233	......
Elastic limit ......pounds per square inch	minimum	30,000	......	......
	maximum	40,000	......	......
	average	36,330	70,000	17,000
Corresponding elongations ......thousandths	minimum	1.333	......	......
	maximum	1.716	......	......
	average	1.567	2.4	1.467
Resistance at failure, on primitive section, pounds per square inch	minimum	76,000	......	......
	maximum	92,120	......	......
	average	86,690	124,200	63,000
Elongation per inch, after rupture ......per cent	minimum	17.0	......	......
	maximum	17.83	......	......
	average	17.39	11.83	19.0
Area of primitive section ......square inch		0.25	0.25	0.25
Reduction of area after rupture, per cent. of primitive section	minimum	47.20	......	......
	maximum	52.20	......	......
	average	50.50	21.40	21.40
Specific gravity		7.8665	......	8.364
Hardness		16.91	......	8.89

Remarks.

In fracture two of the hoop specimens showed fine, silky, cup-shaped ends, and the remaining one dull, silky center, 60 per cent.; fine granular at circumference, 40 per cent., with mottled appearance on surface of bar.

The manufacturer, Sir J. Whitworth & Co., reported the following tests of the hoop metal:

Elastic limit, 23.8 tons per square inch.
Breaking weight, 42.78 tons per square inch.
Ultimate elongation, 19.8 per cent.

The coupling-pin bar is of steel, forged and oil-tempered; the fracture of specimen showed granular, with dull spot at circumference.

The console casting was obtained good on the third trial; the first two were rejected for defective casting.

The fracture of specimen showed a uniform light-yellow color.

An additional specimen, 2".0 length between shoulders, and 0".798 diameter, taken from the accepted casting and tested at this foundry, gave:

Breaking weight, 65,000 pounds per square inch.
Elongation, 22.0 per cent.
Reduction in area, 15.33 per cent.
Specific gravity, 8.4129.

The values adopted from the results of detailed tests, as above, to represent the elastic properties of the trunnion-hoop metal in computing the shrinkages for the construction of the gun were as follows:

Elastic limit, 35,840 pounds, or 16.0 tons per square inch.
Elastic displacement, 1.493 thousandths per linear inch.
Modulus of elasticity, 24,000,000 pounds, or 10,714 tons.

R. BIRNIE, Jr.,
Lieutenant of Ordnance, Inspector.

ADDENDA II.

Inspection report of experimental, steel, 8-inch B. L.

[Extract from measurements of

Hoop.	Distance from marked face.	Interior diameters. No. 1.	No. 2.	No. 3.	No. 4.	Mean.	General mean.	Prescribed.	Eccentricity.	Conicalness.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
A_{12}	0.25	21.999	21.999	21.999	21.999	21.999	....	....	0.	....
	4.125	.999	.999	.999	.999	.999	21.999	22.000	0.	....
	8.0	.999	.999	.999	.999	.999	....	....	0.	....
A_{11}	0.25	21.9995	21.9985	21.9983	21.9983	21.9986	....	....	0.0012	....
	8.75	.9990	.9990	.9990	.9990	.9990	21.9988	22.000	0.	0.0004
	7.25	.9987	.9988	.9988	.9988	.9988	....	....	0.0001	....
A_{1}	9.50	21.9975	21.9975	21.9975	21.9975	21.9975	21.9975	22.000	0.	0.
	2.625	.9975	.9975	.9975	.9975	.9975	....	....	0.	....
	3.50	23.1973	23.1973	23.1973	23.1973	23.1973	....	....	0.	....
	5.875	.1975	.1975	.1975	.1975	.1975	23.1974	23.200	0.	0.0002
	8.125	.1975	.1975	.1975	.1975	.1975	....	....	0.	....
B_{1}	0.25	26.2985	26.2975	26.2965	26.2985	26.2978	....	....	0.002	....
	3.50	.2990	.2975	.2960	.2980	.2976	....	....	0.003	....
	6.75	.2990	.2975	.2960	.2980	.2976	26.2975	26.300	0.003	0.0009
	10.00	.2990	.2975	.2960	.2980	.2976	....	....	0.003	....
	13.25	.2990	.2965	.2950	.2970	.2969	....	....	0.004	....
C_{2}	0.25	15.7495	15.7495	15.7500	15.7500	15.7497	....	....	0.0005	....
	3.92	.7495	.7495	.7495	.7498	.7496	15.7494	15.750	0.0003	0.0007
	7.60	.7490	.7490	.7490	.7490	.7490	....	....	0.	....
C_{4}	0.50	17.7500	17.7490	17.7490	17.7492	17.7493	17.7494	17.750	0.001	0.0002
	2.00	.7500	.7495	.7490	.7495	.7495	....	....	0.001	....
	2.75	15.7498	15.7493	15.7493	15.7500	15.7496	....	....	0.0007	....
	3.75	.7493	.7493	.7495	.7495	.7494	15.7493	15.750	0.0002	0.0006
	7.25	.7490	.7490	.7490	.7490	.7490	....	....	0.	....
D_{1}	0.25	19.7990	19.7987	19.7987	19.7988	19.7988	....	....	0.0003	....
	4.19	.7987	.7985	.7987	.7985	.7986	19.7988	19.8000	0.0002	0.0004
	8.13	.7987	.7987	.7987	.7983	.7986	....	....	0.0004	....
	12.08	.7990	.7990	.7990	.7990	.7990	....	....	0.	....

NOTE.—Allowed variations. For interior diameters (boring), eccentricity, conicalness,

SUMMARY OF MEASUREMENTS FOR

Subject.	A row. Singular hoops.	A row. Dimensions.	B row. Singular hoops.	B row. Dimensions.
		Inches.		*Inches.*
Number of hoops in row	....	(12)	....	(10)
Grand mean diameter of row	....	21.9991	....	26.2988
Mean diameter of largest hoop in row	A_4	22.0001	B_8	26.2999
Variation from mean of row	....	0.0010	....	0.0011
Mean diameter of smallest hoop in row	A_1	21.9975	B_1	26.2975
Variation from mean of row	....	0.0016	....	0.0013
Maximum difference between mean diameters of hoops	$A_4 - A_1$	0.0026	$B_8 - B_1$	0.0024
Largest single diameter measured in row	A_4	22.0005	B_6 and B_8	26.3005
Smallest single diameter measured in row	A_1	21.9975	B_1	26.2950
Difference between largest and smallest single diameters in row.	....	0.0030	....	0.0055

ADDENDA II.

rifle No. 1, *manufactured at West Point Foundry.*

hoops prepared for shrinkage.]

Length on quadrants.							Remarks.
No. 1.	No. 2.	No. 3.	No. 4.	Mean.		Variation from parallelism.	
				Actual.	Prescribed.		
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	
				8.35	8.25		Breech hoop. Left rough at one end to finish when on gun.
7.5015	7.4995	7.4990	7.5010	7.5002	7.50	0.0025	
							Bore.
8.627	8.626	8.627	8.6275	8.6269	8.625	0.0015	Counterbore. Separate lengths of bore and counterbore verified by gauges.
13.508	13.508	13.508	13.508	13.508	13.500	0.	Trunnion hoop. Finished on exterior before shrinkage.
7.8355	7.8360	7.8360	7.8355	7.8357	7.8330	0.0005	
							Counterbore. Length made to templet-gauge (2".5).
7.5120	7.5115	7.5115	7.5115	7.5116	7.5000	0.0005	Bore.
12.8310	12.8300	12.8300	12.8300	12.8300	12.830	0.0010	The lap for hoop A_1 on exterior of this hoop was completely made after shrinkage of hoop. Exteriors of D and C hoops (single hooping) turned to conical form before shrinkage.

and parallelism of ends, 0.003 of an inch; for length of hoops, 0.01 of an inch.

INTERIOR DIAMETERS OF HOOPS.

C row.		D row.		Remarks.
Singular hoops.	Dimensions.	Singular hoops.	Dimensions.	
	Inches.		*Inches.*	
	(9)		(3)	All hoops (except the trunnion hoop) were turned before shrinkage to leave a surplus of 0.1 of an inch on diameters larger than prescribed for the finish.
	15.7491		19.7992	
C_2 and C_3	15.7494	D_3	19.7996	
	0.0003		0.0004	
C_8	15.7486	D_1	19.7988	NOTE.—This addenda is an extract from the complete record of hoop measurements made preparatory to the shrinkage operations. It gives a sample for the ordinary hoops of each row and the several counterbored hoops. For interior diameters a set of four was measured 0.25 of an inch from each face, and other sets (never less than three in all) at intermediate points within the hoop depending upon its length. One length measurement was made between the faces for each quadrant of the hoop.
	0.0005		0.0004	
$C_{2 \text{ and } 3} - C_8$	0.0008	$D_3 - D_1$	0.0008	
C_1	15.7500	D_2	19.8003	
C_{2a}	15.7475	D_1	19.7983	
	0.0025		0.0020	

ADDENDA III.

Inspection report of experimental, steel, 8-inch breech-loading

[Record of shrinkages and

Distance from breech of gun.	Original diameter of bore (before hooping).	First stage.—Jacket and hoops C_1 to C_{34} on tube.				Second stage.—D row of hoops on jacket and C row.					Third stage.—A row of hoops on jacket and D row.	
		Enveloping cylinder.		Shrinkage applied.	Compression of bore (partial).	Enveloping cylinder.		Shrinkage applied.	Compression of bore.		Enveloping cylinder.	
		Designation.	Mean interior diameter.			Designation.	Mean interior diameter.		Partial.	Total.	Designation.	Mean interior diameter.
In.	*Inches.*		*Inches.*	*In.*	*Inches.*		*Inches.*	*In.*	*Inches.*	*Inches.*		*Inches.*
1	10.2710										Hoop A_{12}	21.999
2	.2640											
3	.2630											
4	.2610										Hoop A_{12}	.999
5	.2630											
6	.2627											
7	.2620											
8	.2613										Hoop A_{12}	.999
9	.2650										Hoop A_{11}	21.999
10	.2675											
11	.2695											
12											Hoop A_{11}	.999
13	9.4080	Jacket	13.041	0.011	0.0040							
14	.4078	do	.042	.011	.0058							
15	.4078	do	.043	.010	.0078							
16	.4075	do	.045	.010	.0075						Hoop A_{11}	.999
17	.4078	do	14.047		.0078						Hoop A_{10}	21.998
18	.4078	do	.049	0.012	.0068							
19	.4080	do	.049	.012	.0058							
20	.4080	do	.049	.011	.0050							
21	.4080	do	.049	.012	.0050							
22	.4078	do	.049	.013	.0050						Hoop A_{10}	.998
23	.4078	do	.049	.012	.0050							
24	.4078	do	.049	.012	.0050							
25	.4078	do	.049	.012	.0058							
26	.4075	do	.050	.012	.0055						Hoop A_{10}	.998
27	.4075	do	.050	.011	.0055						Hoop A_9	21.999
28	.4075	do	.050	.011	.0055							
29	.4075	do	.050	.011	.0055							
30	.4072	do	.050	.011	.0052						Hoop A_9	.999
31	.4072	do	.050	.011	.0052							
32	.4072	do	.050	.012	.0062							
33	.4072	do	.051	.012	.0072							
34	.4072	do	.051	.013	.0072						Hoop A_9	22.000
35	.4072	do	.051	.013	.0075						Hoop A_8	22.000
36	.4070	do	.050	.013	.0072							
37	.4072	do	.051	.013	.0082							
38	.4070	do	.051	.013	.0080						Hoop A_8	21.999
39	.4068	do	.051	.013	.0078							
40	.4068	do	.051	.013	.0078							
41	.4065	do	.051	.013	.0075							
42	.4065	do	.051	.013	.0075						Hoop A_8	.999
43	.4068	do	.051	.013	.0080						Hoop A_7	21.999
44	.4068	do	.051	.013	.0078							
45	.4068	do	.051	.013	.0078							
46	.4068	do	.051	.013	.0078						Hoop A_7	.999
47	.4060	do	.051	.012	.0070							
48	.4055	do	.051	.012	.0065							
49	.4055	do	.051	.012	.0065							
50	.4055	do	.051	.012	.0065						Hoop A_7	.999
51	.4055	do	.051	.013	.0065						Hoop A_6	21.998
52	.4052	do	.051	.013	.0062							
53	.4052	do	.051	.012	.0062							
54	.4052	do	.051	.013	.0062						Hoop A_6	.998
55		do	.051	.012								
56		do	.051	.013							Hoop A_6	.999
57		do	.051	.013							Hoop A_5	21.999
58		do	.051	.013								
59		do	.051	.012								
60	7.9078	do	.051	.012	0.0068						Hoop A_5	.999
61	.9072	do	.051	.012	.0072							
62	.9070	do	.051	.013	.0070							
63	.9080	do	.051	.013	.0080						Hoop A_5	.999

ADDENDA III.

rifle No. 1, manufactured at West Point Foundry.

compression of bore.]

Third stage.—A row of hoops on jacket and D row.			Fourth stage.—B row of hoops on A row; hoops C_4 to C_8 on tube.					Distance from muzzle of gun.	Remarks.
Shrinkage applied.	Compression of bore.		Enveloping cylinder.		Shrinkage applied.	Compression of bore.			
	Partial.	Total.	Designation.	Mean interior diameter.		Partial.	Final.		
In.	*Inches.*	*Inches.*		*Inches.*	*In.*	*Inches.*	*Inches.*	*In.*	
0.034		0.0030						257	Over breech-recess of jacket. Shrinkage of hoop B_{10} and part of B_9 made relatively light to avoid over compression of the threaded recess. A heavier shrinkage given to breech than to forward end of B_{10} to give the hoop a secure hold.
.034		.0030						256	
.033		.0038				0.0007		255	
.033		.0030	Hoop B_{10}..	26.298	0.019	.0020		254	
.033		.0040			.021	.0023		253	
.034		.0045			.021	.0017		252	
.034		.0045			.017	.0020		251	
.034		.0043	Hoop B_{10}..	.299	.016	.0018		250	
.033		.0065			.016	.0015		249	
.033		.0060			.015	.0020		248	
.033		.0070	Hoop B_{10}..	.300	.015	.0028		247	
.033			Hoop B_9...	26.298	.016			246	
.032	0.0060	0.0100			.017	0.0030	0.0130	245	Over breech end of tube.
.032	.0058	.0118			.029	.0037	.0158	244	
.033	.0058	.0136	Hoop B_9...	.298	.034	.0037	.0173	243	
.033	.0060	.0135			.034	.0035	.0170	242	
.033	.0050	.0128			.033	.0042	.0170	241	Over chamber of tube.
.033	.0050	.0118			.033	.0038	.0156	240	
.033	.0052	.0110			.033	.0045	.0155	239	
.033	.0055	.0105	Hoop B_9...	.298	.033	.0040	.0145	238	
.033	.0050	.0100	Hoop B_8...	26.300	.031	.0045	.0145	237	
.033	.0048	.0098			.031	.0047	.0145	236	
.033	.0053	.0103			.032	.0042	.0145	235	
.033	.0048	.0098	Hoop B_8...	.299	.033	.0047	.0145	234	
.033	.0048	.0106			.032	.0042	.0148	233	
.033	.0045	.0100			.032	.0043	.0143	232	
.033	.0045	.0100			.031	.0040	.0140	231	
.033	.0045	.0100	Hoop B_8...	.300	.031	.0043	.0143	230	
.033	.0050	.0105	Hoop B_7...	26.298	.032	.0033	.0138	229	
.033	.0048	.0100			.032	.0035	.0135	228	
.033	.0045	.0097			.032	.0037	.0134	227	
.033	.0045	.0107			.032	.0042	.0149	226	
.032	.0040	.0112	Hoop B_7..	.299	.033	.0033	.0145	225	
.032	.0052	.0124			.033	.0030	.0154	224	
.033	.0053	.0128			.033	.0027	.0155	223	
.033	.0058	.0130	Hoop B_7...	.299	.033	.0025	.0155	222	
.033	.0050	.0132	Hoop B_6...	26.299	.033	.0030	.0162	221	
.033	.0055	.0135			.034	.0065	.0170	220	
.034	.0055	.0133			.034	.0037	.0170	219	
.034	.0060	.0138			.034	.0025	.0163	218	
.034	.0060	.0135	Hoop B_6...	.299	.033	.0028	.0163	217	
.034	.0060	.0135			.033	.0030	.0165	216	
.034	.0058	.0138			.033	.0032	.0170	215	
.034	.0060	.0138	Hoop B_6...	.299	.034	.0032	.0170	214	
.033	.0060	.0138	Hoop B_5...	26.298	.035	.0032	.0170	213	
.034	.0058	.0136			.035	.0034	.0170	212	
.034	.0060	.0130			.035	.0035	.0165	211	
.034	.0055	.0120			.035	.0040	.0160	210	
.035	.0055	.0120	Hoop B_5...	.298	.035	.0040	.0160	209	
.035	.0055	.0120			.035	.0037	.0157	208	
.035	.0055	.0120			.034	.0040	.0160	207	
.035	.0058	.0120	Hoop B_5...	.299	.034	.0037	.0157	206	
.035	.0050	.0112	Hoop B_4...	26.299	.034	.0045	.0157	205	
.035	.0050	.0112			.034	.0038	.0150	204	
.034					.034			203	Slope at front of chamber compression could not be measured.
.034					.034			202	
.034			Hoop B_4..	.299	.033			201	
.034					.033			200	
.034					.033			199	
.034	0.0040	0.0108	Hoop B_4..	.299	.033	0.0030	0.0138	198	
.034	.0035	.0107	Hoop B_3..	26.299	.033	.0020	.0127	197	
.034	.0040	.0110			.033	.0020	.0130	196	
.034	.0035	.0115			.034	.0023	.0138	195	

ADDENDA III—Continued.

Inspection report of experimental, steel, 8-inch breech-loading rifle

Distance from breech of gun.	Original diameter of bore (before hooping).	First stage.—Jacket and hoops C_1 to C_{3a} on tube. Enveloping cylinder. Designation.	Mean interior diameter.	Shrinkage applied.	Compression of bore (partial).	Second stage.—D row of hoops on jacket and C row. Enveloping cylinder. Designation.	Mean interior diameter.	Shrinkage applied.	Compression of bore. Partial.	Total.	Third stage.—A row of hoops on jacket and D row. Enveloping cylinder. Designation.	Mean interior diameter.
In.	Inches.		Inches.	In.	Inches.		Inches.	In.	Inches.	Inches.		Inches.
64	.9080	Jacket	.051	.013	.0080						Hoop A_4	22.000
65	.9000	do	.051	.013	.0080							
66	.9088	do	.051	.014	.0080							
67	.9082	do	.051	.014	.0072						Hoop A_4	.000
68	.9080	do	.051	.014	.0070							
69	.9078	do	.050	.015	.0068							
70	.9068	do	.050	.015	.0060							
71	.9068	do	.050	.015	.0068						Hoop A_4	.000
72	.9070	do	.050	.014	.0070						Hoop A_3	22.000
73	.9078	do	.050	.014	.0078							
74	.9075	do	.051	.013	.0060							
75	.9078	do	.052	.012	.0058							
76	.9082	do	.052	.012	.0054						Hoop A_3	.000
77	.9082	do	.052	.013	.0054							
78	.9085	do	.052	.014	.0057							
79	.9085	do	.052	.014	.0057							
80	.9098	do	.052	.014	.0068						Hoop A_3	.000
81	.9095	do	.052	.014	.0063						Hoop A_2	21.999
82	.9100	do	.052	.014	.0072							
83	.9095	do	.052	.014	.0067							
84	.9098	do	.052	.014	.0066							
85	.9095	do	.052	.014	.0067						Hoop A_2	22.000
86	.9098	do	.052	.013	.0066							
87	.9095	do	.052	.013	.0063							
88	.9095	do	.052	.013	.0057						Hoop A_2	.000
89	.9115	do	.052	.013	.0067						Hoop A_1	21.997
90	.9115	do	.052	.014	.0065							
91	.9112	do	.051	.014	.0064						Hoop A_1	.997
92	.9112	do	.050	.014	.0072						Hoop A_1*	23.197
93	.9105	do	.051	.014	.0065				0.0000	0.0065		
94	.9108	Jacket*	14.597	0.011	.0058				.0013	.0071	Hoop A_1	.197
95	.9112	do	.598	.011	.0052	Hoop D_1	19.799	0.027	.0023	.0075		
96	.9092	do	.598	.011	.0052			.027	.0028	.0080	Hoop A_1	.197
97	.9088	do	.598	.011	.0040			.027	.0028	.0068		
98	.9095	do	.598	.011	.0047			.027	.0027	.0074		
99	.9108	do	.598	.011	.0038	Hoop D_1	.799	.027	.0040	.0078		
100	.9110	Hoop C_1	15.749	0.015	.0040			.027	.0040	.0080		
101	.9105	do	.749	.013	.0037			.027	.0038	.0075		
102	.9115			.013	.0037			.027	.0048	.0085		
103	.9115	Hoop C_1	.750	.015	.0035	Hoop D_1	.799	.027	.0052	.0087		
104	.9115	Hoop C_2	15.750	.015	.0037			.027	.0053	.0090		
105	.9120			.015	.0048			.027	.0042	.0090		
106	.9115			.015	.0037			.026	.0050	.0087		
107	.9120	Hoop C_2	.750	.015	.0042	Hoop D_1	.799	.025	.0048	.0090		
108	.9118			.015	.0050	Hoop D_2	19.800	.024	.0038	.0088		
109	.9118			.016	.0048			.024	.0042	.0090		
110	.9118			.016	.0050			.024	.0040	.0090		
111	.9108	Hoop C_2	.750	.016	.0040			.025	.0046	.0086		
112	.9105	Hoop C_3	15.749	.016	.0035	Hoop D_2	.799	.025	.0040	.0075		
113	.9115			.016	.0035			.026	.0050	.0085		
114	.9112			.016	.0040			.025	.0050	.0090		
115	.9115	Hoop C_3	.749	.016	.0043			.024	.0034	.0077		
116	.9110			.016	.0032	Hoop D_2	.799	.023	.0043	.0075		
117	.9015			.016	.0045	Hoop D_3	19.799	.023	.0038	.0083		
118	.9112	Hoop C_3	.749	.017	.0034			.023	.0043	.0077		
119	.9105	Hoop C_{3a}	15.748	.018	.0035			.023	.0038	.0073		
120	.9110			.018	.0050			.023	.0030	.0080		
121	.9105			.017	.0045	Hoop D_3	.799	.023	.0030	.0075		
122	.9110	Hoop C_{3a}	.749	.017	.0050			.023	.0028	.0078		
123	.9115			.017	.0055			.023	.0010	.0065		
124	.9125	Hoop C_{3a}	.749	.016	.0047			.023	.0018	.0065		
125	.9120			.016	.0032			.023	.0020	.0052		
126	.9128	Hoop C_{3a}	.750	.015	.0038	Hoop D_3	.800	.023	.0012	.0050		
127	.9122			.015	.0032				.0010	.0042		
128	.9120			016	.0022				.0000	.0022		
129	.9112	Hoop C_{3a}	.749	.016	.0014							
130	.9112				.0014							
131	.9102				.0022							

* Counterbore.

ADDENDA III—Continued.

***No.* 1, *manufactured at West Point Foundry*—Continued.**

Third stage.—A row of hoops on jacket and D row.			Fourth stage.—B row of hoops on A row; hoops C_4 to C_8 on tube.					Distance from muzzle of gun.	Remarks.
Shrinkage applied.	Compression of bore.		Enveloping cylinder.		Shrinkage applied.	Compression of bore.			
	Partial.	Total.	Designation.	Mean interior diameter.		Partial.	Final.		
In.	*Inches.*	*Inches.*		*Inches.*	*In.*	*Inches.*	*Inches.*	*In.*	
.034	.0035	.0115			.034	.0015	.0130	194	
.034	.0040	.0120	Hoop B_3 ..	.299	.035	.0030	.0150	193	
.034	.0040	.0120			.035	.0028	.0148	192	
.034	.0040	.0112			.035	.0032	.0144	191	
.034	.0040	.0110	Hoop B_3 ..	2.99	.035	.0020	.0130	190	
.033	.0050	.0118	Hoop B_2 ..	26.300	.034	.0020	.0138	189	
.033	.0043	.0103			.034	.0035	.0138	188	
.033	.0035	.0103			.034	.0035	.0138	187	
.034	.0042	.0112	Hoop B_2 ..	.299	.034	.0023	.0135	186	
.034	.0040	.0118			.033	.0028	.0146	185	
.034	.0045	.0105			.032	.0025	.0130	184	
.034	.0040	.0098	Hoop B_2 ..	.300	.032	.0030	.0128	183	
.033	.0016	.0100	Hoop B_1 †	26.298	.032	.0030	.0130	182	
.033	.0043	.0097			.032	.0033	.0130	181	
.033	.0048	.0105			.031	.0020	.0125	180	
.033	.0046	.0103	Hoop B_1 ..	.298	.031	.0032	.0135	179	
.034	.0040	.0108			.031	.0028	.0136	178	
.034	.0042	.0105			.031	.0025	.0130	177	
.034	.0046	.0118	Hoop B_1 ..	.298	.031	.0020	.0138	176	
.034	.0040	.0107			.031	.0018	.0125	175	
.034	.0042	.0108			.031	.0018	.0126	174	
.034	.0043	.0110			.031	.0027	.0137	173	
.034	.0044	.0110	Hoop B_1 ..	.298	.031	.0018	.0128	172	
.034	.0050	.0113			.031	.0007	.0120	171	
.033	.0053	.0110			.031	.0003	.0113	170	
.032	.0058	.0125	Hoop B_1 ..	.297	.031	.0000	.0125	169	End of Brow (trunnion hoop).
.032	.0055	.0120					.0120	168	
.032	.0058	.0122					.0122	167	Shoulder of jacket.
.033	.0052	.0124					.0124	166	
.933	.0058	.0123					.0123	165	
.034	.0049	.0120					.0120	164	
.034	.0045	.0120					.0120	163	
.034	.0038	.0112					.0112	162	End of A row; its application produces an increased compression of bore for 6 inches forward.
	.0038	.0106					.0106	161	
	.0033	.0107					.0107	160	
	.0030	.0098					.0098	159	
	.0018	.0098					.0008	158	
	.0018	.0093					.0093	157	
	.0008	.0093					.0093	156	
	.0000	.0087					.0087	155	
							.0090	154	
							.0090	153	
							.0087	152	
							.0090	151	
							.0086	150	
							.0090	149	
							.0090	148	
							.0086	147	
							.0075	146	
							.0085	145	
							.0090	144	
							.0077	143	
							.0075	142	
							.0083	141	
							.0077	140	
							.0073	139	
							.0080	138	
						0.0000	.0075	137	
						.0007	.0085	136	
						.0020	.0085	135	
						.0010	.0075	134	
						.0013	.0065	133	
						.0010	.0060	132	End of D row of hoops.
						.0020	.0062	131	Lap of hoop C_4.
			Hoop C_4 *	17.749	.011	.0030	.0052	130	
				.749	.013	.0033	.0047	129	
			Hoop C_4 ..	15.750	.015	.0043	.0057	128	
			....do	.749	.016	.0040	.0062	127	

† Trunnion.

ADDENDA III—Continued.

Inspection report of experimental, steel, 8-inch breech-loading rifle

Distance from breech of gun.	Original diameter of bore (before hooping).	First stage.—Jacket and hoops C_1 to C_{18} on tube.				Second stage.—D row of hoops on jacket and C row.					Third stage.—A row of hoops on jacket and D row.	
		Enveloping cylinder.		Shrinkage applied.	Compression of bore (partial).	Enveloping cylinder.		Shrinkage applied.	Compression of bore.		Enveloping cylinder.	
		Designation.	Mean interior diameter.			Designation.	Mean interior diameter.		Partial.	Total.	Designation.	Mean interior diameter.
In.	Inches.		Inches.	In.	Inches.		Inches.	In.	Inches.	Inches.		Inches.
132	.9100				.0022							
133	.9100				.0010							
134	.9130				.0010							
135	.9125				.0000							
136	.9115											
137	.9115											
138	.9122											
139	.9120											
140	.9140											
141	.9140											
142	.9130											
143	.9115											
144	.9108											
145	.9095											
146	.9092											
147	.9092											
148	.9170											
149	.9170											
150	.9165											
151	.9160											
152	.9160											
153	.9165											
154	.9165											
155	.9165											
156	.9170											
157	.9170											
158	.9172											
159	.9172											
160	.9168											
161	.9158											
162	.9172											
163	.9172											
164	.9168											
165	.9168											
166	.9155											
167	.9165											
168	.9155											
169	.9155											
170	.9155											
171	.9150											
172	.9150											

ADDENDA III—Continued.

No. 1, manufactured at West Point Foundry—Continued.

Third stage.—A row of hoops on jacket and D row.			Fourth stage.—B row of hoops on A row; hoops C_4 to C_8 on tube.					Distance from muzzle of gun.	Remarks.
Shrinkage applied.	Compression of bore.		Enveloping cylinder.		Shrinkage applied.	Compression of bore.			
	Partial.	Total.	Designation.	Mean interior diameter.		Partial.	Final.		
In.	*Inches.*	*Inches.*		*Inches.*	*In.*	*Inches.*	*Inches.*	*In.*	
					.017	.0038	.0060	126	
					.017	.0050	.0060	125	
			Hoop C_4	.749	.017	.0052	.0062	124	
			Hoop C_5	15.749	.017	.0060	.0060	123	
					.017	.0055	.0055	122	
					.017	.0045	.0045	121	
					.017	.0052	.0052	120	
			Hoop C_5	.749	.017	.0042	.0042	119	
					.017	.0068	.0068	118	
					.017	.0058	.0058	117	
			Hoop C_5	.749	.016	.0040	.0040	116	
			Hoop C_6	15.749	.016	.0040	.0040	115	
					.016	.0048	.0048	114	
					.016	.0040	.0040	113	
					.016	.0047	.0047	112	
			Hoop C_6	.749	.016	.0042	.0042	111	
					.016	.0040	.0040	110	
					.016	.0040	.0040	109	
			Hoop C_6	.749	.016	.0045	.0045	108	
			Hoop C_7	15.749	.016	.0040	.0040	107	
					.016	.0038	.0038	106	
					.016	.0040	.0040	105	
					.016	.0050	.0050	104	
			Hoop C_7	.749	.016	.0040	.0040	103	
					.016	.0042	.0042	102	
					.016	.0040	.0040	101	
					.016	.0044	.0044	100	
			Hoop C_7	.749	.016	.0042	.0042	99	
			Hoop C_8	15.749	.017	.0038	.0038	98	
					.017	.0038	.0038	97	
					.017	.0040	.0040	96	
			Hoop C_8	.748	.017	.0037	.0037	95	
					.017	.0028	.0028	94	
					.017	.0028	.0028	93	
					.017	.0015	.0015	92	
			Hoop C_8	.749	.018	.0020	.0020	91	End of hooping.
						.0010	.0010	90	
						.0010	.0010	89	
						.0010	.0010	88	
						.0010	.0010	87	End of compression.
						.0000	.0000	86	

ADDENDA IV.

Inspection report of experimental, steel, 8-inch breech-loading

[Record of shrink

Jacket and hoops.	Intervals of time.						Expansions and temperature of metal.					
							Prescribed expansions.			Final expansions.		
	In furnace heating.	Furnace to position.	Position to pressure applied.	Furnace to water on.	Pressure applied.	Water applied.	Gauge-rod set.	Expansion.	Clearance.	Absolute.	Relative.	Highest temp'at're (estim'd).
	h. m.	*m.*	*m.*	*m.*	*m.*	*h. m.*	*In.*	*In.*	*In.*	*In.*	1000s.	°(*F.*)
Jacket, Counter bore	......	......	......	......	......	......	13.087	0.046	0.035	......	......	......
Jacket, Main bore	9 21	7.25	......	11.0	......	*2.0	14.101	0.051	0.037*	......	......	......
Jacket, Muzzle	......	......	......	......	......	......	......	......	......	0.065	4.45	740
C row, part of—												
Hoop C1	1 35	3.0	1.5	7.0	15.5	8.0	15.795	0.046	0.030	0.056	3.56	600
Hoop C2	1 56	0.5	1.0	1.5	20.5	18.5	15.795	0.046	0.030	0.064	4.06	680
Hoop C3	1 17	0.75	0.25	2.5	15.5	20.0	15.795	0.046	0.030	0.060	3.81	640
Hoop C3a	1 44	0.5	1.75	2.5	30.0	30.0	15.795	0.046	0.030	0.067	4.25	710
D row.												
Hoop D1	2 29	1.25	1.25	3.5	27.0	30.0	19.860	0.061	0.035	0.066	3.34	565
Hoop D2	2 57	1.25	1.5	4.0	20.0	21.0	19.860	0.061	0.035	0.075	3.79	635
Hoop D3	1 13	1.00	1.25	3.0	21.0	19.0	19.860	0.061	0.035	0.067	3.38	570
C row, finish of—												
Hoop C4	2 14	1.00	1.00	2.5	11.0	13.0	15.795	0.046	0.030	0.040	2.54	450
Hoop C5	2 38	0.75	1.75	3.0	27.0	26.0	15.795	0.046	0.030	0.048	3.05	525
Hoop C6	1 16	0.75	1.25	3.0	25.0	27.0	15.795	0.046	0.030	0.046	2.92	505
Hoop C7	1 28	0.75	1.25	2.5	20.0	27.0	15.795	0.046	0.030	0.060	3.81	640
Hoop C8	0 51	0.75	1.0	2.0	21.0	20.0	15.795	0.046	0.030	0.048	3.05	525
A row.												
Hoop A1	2 54	1.5	1.25	3.5	33.0	33.0	22.07	0.072	0.036	0.101	4.59	760
Hoop A2	1 40	2.0	1.5	5.5	19.0	19.0	22.07	0.070	0.036	0.109	4.95	815
Hoop A3	1 32	4.0	1.25	5.5	15.0	19.0	22.07	0.070	0.036	0.090	4.09	685
Hoop A4	0 52	1.5	1.75	4.0	17.0	18.0	22.07	0.070	0.036	0.076	3.45	590
Hoop A5	1 11	2.0	1.5	3.5	17.0	19.0	22.07	0.071	0.036	0.077	3.50	595
Hoop A6	1 20	1.5	2.5	4.0	15.0	17.0	22.07	0.071	0.036	0.099	4.50	745
Hoop A7	0 54	2.25	1.25	4.0	19.0	19.0	22.07	0.071	0.036	0.074	3.36	575
Hoop A8	1 08	2.0	1.5	3.5	17.0	16.0	22.07	0.071	0.036	0.074	3.36	575
Hoop A9	1 02	1.75	1.0	3.0	17.0	15.0	22.07	0.070	0.036	0.086	3.91	655
Hoop A10	0 51	1.25	1.25	3.0	13.0	15.0	22.07	0.072	0.036	0.073	3.32	565
Hoop A11	0 48	1.5	2.0	4.0	12.0	13.0	22.07	0.071	0.036	0.065	2.95	510
Hoop A12	0 51	1.0	2.5	3.5	15.0	17.0	22.07	0.071	0.036	0.081	3.68	620
B row.												
Hoop B1 (trunnion)	3 15	2.0	1.25	3.5	38.0	49.0	26.37	0.072	0.036	0.088	3.35	570
Hoop B2	1 11	1.75	1.25	3.0	23.0	27.0	26.37	0.070	0.036	0.092	3.50	595
Hoop B3	1 49	1.5	1.5	3.0	27.0	28.0	26.37	0.071	0.036	0.106	4.03	675
Hoop B4	2 22	1.5	1.0	3.0	25.0	27.0	26.37	0.071	0.036	0.109	4.14	690
Hoop B5	1 29	1.5	1.75	3.0	21.0	23.0	26.37	0.072	0.036	0.103	3.92	655
Hoop B6	1 06	1.25	2.0	3.5	19.0	23.0	26.37	0.071	0.036	0.073	2.78	485
Hoop B7	1 06	1.75	1.75	3.5	21.0	19.0	26.37	0.071	0.036	0.078	2.97	515
Hoop B8	1 22	2.5	2.0	4.5	22.0	24.0	26.37	0.070	0.036	0.088	3.35	570
Hoop B9	1 31	2.5	1.5	4.0	17.0	22.0	26.37	0.072	0.033	0.084	3.19	545
Hoop B10	1 20	1.0	1.25	2.25	22.0	18.0	26.87	0.071	0.036	0.101	3.84	645

*Nearly.

ADDENDA IV.

rifle No. 1, manufactured at West Point Foundry.

age operations.]

Openings at joints on cooling.					Remarks.
Top.	Right.	Bottom.	Left.	Average.	
In.	*In.*	*In.*	*In.*	*In.*	
....	....	....	....	....	Jacket heated, laid horizontally on iron car in hot-air furnace.
....	....	....	....	....	Guage-rod (disk) entered main bore freely after 7 hours 30 minutes heating, and counterbore (freely) after 8 hours 30 minutes heating.
....	....	....	....	....	
0.28	....	0.013	....	0.02	The temperatures are stated as so many degrees above 0, F.
....	0.008	....	0.012	0.01	
....	....	....	....	0.003	
....	....	....	....	0.003	
....	....	....	....	0.003	
....	....	....	....	....	
....	0.013	0.009	0.013	....	
....	....	....	....	0.003	
0.004	0.004	0.004	0.004	0.004	
....	....	....	0.004	....	Apparent contact at top of joint.
....	....	....	....	0.004	Apparent contact at bottom of joint.
....	0.004	....	0.004	....	Apparent contact at top and bottom of joint.
0.004	0.004	0.004	0.004	0.004	
0.004	0.005	0.004	0.005	0.004	
0.012	0.012	0.012	0.012	0.012	
....	....	0.003	0.004	....	Apparent contact at top of joint.
....	0.004	0.003	0.004	....	Do.
....	0.007	....	0.005	....	Apparent contact at points around top.
....	....	....	0.007	....	Very close at top, increasing thence around to left.
....	....	....	....	0.004	
....	....	....	....	0.004	Apparent contact about top of joint.
....	....	....	....	0.004	
....	0.004	0.004	0.007	....	Apparent contact at top of joint.
....	0.005	....	0.005	....	Apparent contact at top and bottom of joint.
....	0.008	....	0.008	....	Apparent contact at top; 0''.003 in upper quadrants.
					Good spray from sprinkler for A_2 and following.
0.005	0.005	0.005	0.007	....	
0.005	0.010	0.005	0.010	....	
0.002	0.005	0.005	0.005	....	
0.007	0.014	0.010	0.014	....	
0.007	0.009	0.006	0.009	....	
....	0.004	0.005	0.004	....	Top of joint closed at points.
0.003	0.007	0.005	0.005	....	
....	0.006	0.006	0.006	....	Top of joint closed at points.
0.005	0.006	0.005	0.007	....	
0.008	0.007	0.007	0.007	....	

ADDENDA V.

Inspection report of experimental, steel, 8-inch breech-loading rifle No. 1, manufactured at West Point Foundry.

[Record of measurements of finished bore and rifling.]

Distance from muzzle.	Diameter of bore. Before rifling. Horizontal.	Diameter of bore. Before rifling. Vertical.	Diameter of bore. After rifling.	Distance from muzzle.	Diameter of bore. Before rifling. Horizontal.	Diameter of bore. Before rifling. Vertical.	Diameter of bore. After rifling.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1	7.999	7.999	*	67	8.000	8.000	
2	.999	.9995		68	.000	7.9995	
3	.9995	.9995		69	.000	8.000	
4	.9995	.9995		70	.000	.000	8.000
5	8.000	8.000		71	7.9995	.000	
6	.000	.000		72	.9995	.000	
7	.000	.000		73	.9995	.000	
8	.000	.000		74	.9995	.000	
9	.000	.000		75	.9995	.000	
10	.000	.0005		76	.9995	.000	
11	.000	.0005		77	.9995	.000	
12	.0005	.000		78	.9995	.000	
13	.000	.000		79	.9995	.000	
14	.000	.000		80	.9995	.000	8.000
15	.0005	.000		81	.9995	.000	
16	.000	.0005		82	.9995	.000	
17	.000	.0005		83	.9995	.000	
18	.000	.0005		84	.9995	.000	
19	.0005	.0005		85	.9995	.000	
20	.0005	.0005	8.002	86	.9995	.000	
21	.0005	.0005		87	.9995	.000	
22	.0005	.0005		88	.9995	.000	
23	.0005	.000		89	.9995	7.9995	
24	.0005	.000		90	.9995	.9995	8.001
25	.0005	.000		91	.9995	.9995	
26	.0005	.0005		92	.9995	.9995	
27	.000	.000		93	.9995	.9995	
28	.0005	.0005		94	.9995	.9995	
29	.0005	.0005		95	.9995	.9995	
30	.000	.000	8.000	96	.9995	.9995	
31	.000	.000		97	.9995	.9995	
32	.000	.000		98	.9995	.999	
33	.0005	.000		99	.999	.9995	
34	.000	.000		100	.9995	.9995	8.0005
35	.000	.000		101	.9995	.9995	
36	.000	.000		102	.999	.9995	
37	.000	.000		103	7.999	7.9995	
38	.000	.000		104	.999	.9995	
39	.000	.000		105	.9995	.9995	
40	.000	.000	8.000	106	.9995	.9995	
41	.000	.000		107	.9995	.9995	
42	.000	.000		108	.999	.9995	
43	.000	.000		109	.999	.999	
44	.000	.000		110	.9995	.999	8.000
45	.000	.000		111	.9995	.9995	
46	.000	.000		112	.9995	.999	
47	.000	.000		113	.9995	.999	
48	.000	.000		114	.9995	.999	
49	.000	.000		115	.999	.999	
50	.000	.000	8.000	116	.9995	.996	
51	.000	.000		117	.999	.999	
52	8.000	8.000		118	.999	.999	
53	.000	.000		119	.999	.9995	
54	.000	.000		120	.999	.999	8.000
55	.000	.000		121	.9995	.9995	
56	.000	.000		122	.9995	.9995	
57	.000	.000		123	.999	.9995	
58	.000	.000		124	.999	.9995	
59	.000	.000		125	.999	.9995	
60	.000	.000	8.000	126	.999	.9995	
61	.000	.000		127	.999	.9995	
62	7.9995	.000		128	.999	.9995	
63	.9995	.000		129	.999	.9995	
64	8.000	.000		130	.999	.9995	8.000
65	.000	.000		131	.999	.9995	
66	.000	.000		132	.999	.9995	

* Measured across lands, three points in star gauge.

Inspection report of experimental, steel, 8-inch breech-loading rifle No. 1, &c.—Continued.

Distance from muzzle.	Diameter of bore.			Distance from muzzle.	Diameter of bore.		
	Before rifling.		After rifling.		Before rifling.		After rifling.
	Horizontal.	Vertical.			Horizontal.	Vertical.	
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
133	7.999	7.9995	....	163	.000	.0005	....
134	.999	.9995	....	164	.000	.0005	....
135	.999	.9995	....	165	.000	.0005	....
136	.999	.9995	....	166	.001	.000	....
137	.999	.9995	....	167	.001	.001	....
138	.9995	.9995	....	168	.001	.001	....
139	.9995	.9995	....	169	.001	.001	....
140	.9995	.9995	8.000	170	.001	.0015	8.0015
141	.999	.9995	....	171	.001	.0015	....
142	.999	.9995	....	172	.001	.002	....
143	.999	.9995	....	173	.002	.0025	....
144	.999	.9995	....	174	.002	.0025	....
145	.999	.9995	....	175	.002	.0025	....
146	.999	.9995	....	176	.003	.003	....
147	.999	.999	....	177	.003	.0035	....
148	.999	.9995	....	178	.003	.0035	....
149	.999	.9995	....	179	.003	.004	....
150	.999	.9995	8.000	180	.004	.0035	8.005
151	.999	.9995	....	181	.004	.0045	....
152	.999	.9995	....	182	.004	.0045	....
153	.9995	.9995	....	183	.005	.0045	....
154	7.9995	7.9995	....	184	.006	.0045	....
155	.9995	.9995	....	185	.0055	.0055	....
156	8.000	.9995	....	186	.006	.0055	....
157	.000	.9995	....	187	.0065	.0055	....
158	.000	.9995	....	188	.007	.0065	....
159	.000	.9995	....	189	.007	.0065	....
160	7.9995	.9995	8.0005	190	.007	.007	8.007
161	8.000	8.000	....	191	.007	.007	....
162	.000	.000	....				

Distance from breech.	Diameter of powder chamber.		Distance from breech.	Diameter of powder chamber.	
	Horizontal.	Vertical.		Horizontal.	Vertical.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
16	9.498	9.498	36	.499	.498
17	.498	.498	37	.499	.499
18	.4985	.498	38	.499	.4985
19	.499	.498	39	.498	.4985
20	.498	.498	40	.499	.4985
21	.4985	.4985	41	.499	.4985
22	.498	.4985	42	.499	.499
23	.499	.4985	43	.4985	.499
24	.499	.499	44	.499	.499
25	.498	.4985	45	.498	.499
26	.498	.4985	46	9.499	9.499
27	.499	.498	47	.499	.499
28	.499	.499	48	.499	.499
29	.499	.498	49	.499	.499
30	.499	.498	50	.499	.499
31	.499	.4985	51	.499	.499
32	.498	.499	52	.4985	.499
33	.498	.498	53	.498	.499
34	.498	.4985	54	.499	4.985
35	.499	.498			

Distance from breech.	Diameter of shot chamber.		Distance from breech.	Diameter of shot chamber.	
	Horizontal.	Vertical.		Horizontal.	Vertical.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
62.5	8.201	8.200	64.0	.194	.195
63.0	.204	.204	64.5	.195	.196
63.5	.204	.2035	65.0	.197	.199

RIFLING.

Inches from muzzle.	Measurements of three grooves each. Star gauge set to 8.00 inches.															Mean.	Depth of grooves.
	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	*Inches.*	*Inches.*
10	121	124	125	125	125	121	121	121	121	122	122	123	126	123	121	8.123	0.0615
30	121	125	124	125	125	121	121	120	121	122	122	122	124	123	120	.122	.061
50	123	126	126	126	126	124	121	122	122	124	123	123	124	124	123	.124	.062
70	123	127	127	128	128	126	123	125	125	126	124	125	128	127	123	.125	.0625
90	124	129	128	130	130	127	124	126	125	126	125	129	130	129	126	.127	.0635
110	121	127	127	128	127	124	122	124	125	126	125	127	129	125	123	.125	.0625
130	120	125	124	125	125	121	121	122	122	123	124	124	126	125	122	.123	.0615
150	121	122	122	124	123	120	120	121	121	122	121	123	124	123	120	.122	.061
170	119	122	121	122	121	119	120	120	120	120	120	122	122	121	120	.121	.0605
190	119	121	120	120	118	118	117	117	118	117	119	121	121	121	119	.119	.0595
191	124	121	119	120	118	119	116	118	118	117	119	121	121	120	119	.119	.0595
Mean																8.123	0.0615

APPENDIX 19.

CONSTRUCTION REPORT OF 8-INCH YATES B. L. RIFLE (CONVERTED).

BY CAPT. D. A. LYLE, ORDNANCE DEPARTMENT.

This rifle is a conversion from 10-inch Rodman smooth-bore gun No. 182 (W. P. F.), by lining with a Nashua steel tube, screwing a cast-iron extension piece on the muzzle, and attaching a breech mechanism of Midvale steel.

NOMENCLATURE.

1. Cast-iron body (10-inch Rodman S. B. gun).
2. Extension piece (of cast iron, to lengthen the muzzle of piece).
3. Steel tube.
4. Securing pin.
5. Breech clamps (2 of Midvale steel).
6. Breech clamps assembling (bolts) (2).
7. Firing-pin recess.
8. Firing-pin.
9. Firing-pin spring.
10. Firing-pin bushing.
11. Hammer.
12. Hammer pivot.
13. Latch.
14. Latch spring and pivot.
15. Latch point.
16. Cam lever and pivot.
17. Cam pins (2).
18. Cartridge head (bronze).
19. Steel bushing for seat of priming cartridge.

DESCRIPTION AND FABRICATION.

The body.

The body is the ordinary 10-inch Rodman S. B. gun, pierced through at the breech and bored out to a diameter of 10.5 inches the whole length for the reception of the steel tube.

The rear end of the casing is counterbored to a diameter of 12 inches for 9 inches from the rear end, to accommodate the shoulder of the tube. The front end has a screw tenon cut upon its exterior, to which the extension piece is fitted. This extension piece has its interior bored to correspond with the casing.

The exterior of the casing in rear of the trunnions is turned down to a diameter of 28 inches between the shoulders, and to a diameter of 30 inches measured over the first two shoulders, and to 29.9 inches over the rear shoulder.

Three projecting annular shoulders are left on the exterior to engage corresponding bearing surfaces on the interior of the steel breech clamps. The planes of these shoulders are perpendicular to the axis of the piece.

The longitudinal sections of these annular fillets are trapezoidal. The top of the rear shoulder merges into the curved surface of the breech by a surface whose radius is 11 inches. The radius of the breech is 34 inches. The shoulder of the casing in front of the clamps is curved in longitudinal section.

The tube.

The tube is made of Nashua steel and is cylindrical upon its exterior. The cylindrical shoulder at the rear end has a greater diameter than the rest of the tube. The tube is a mechanical fit, with an allowed *play* of 0.003 inch and was inserted by pressure. The tube is kept from turning, under the action of firing, by the insertion of a securing pin in the under side, 3 feet 6 inches in front of the axis of the trunnions. This piece engages the steel tube in a recess 0.25-inch in depth. The 8-inch bore has polygroove rifling, with an equal number of lands and grooves. The chamber is concentric with the bore and is formed of 3 conical and 2 cylindrical surfaces. The grooves run out in the first conical surface, which forms the throat of the chamber. The rear end of the chamber is cylindrically counterbored for .45-inch to furnish a recessed seat for the head of the composition loading tube or "cartridge head." The rear conical surface (11.7 inches long) just in front of the counterbore forms the seat for the longitudinal walls of this "cartridge head" and has its taper adjusted to facilitate the removal of the latter.

A vertical slot is made in the lower edge of the rear end of the tube to enable the projecting rim of the cartridge head to be gripped and started in case of its sticking.

The two breech clamps.

These are symmetrical in form and are made from castings of Midvale steel. The exterior of the clamps is cylindrical, and rounded in rear to embrace and clasp the breech like a shell. They are held together in front by two assembling bolts, one above and one below, which are screwed into the cast-iron casing. These bolts pass through eye-holes in the ears that project from the front edges of the clamps. The interior cylindrical surfaces of the clamps have annular grooves cut out to correspond with the fillets in the casing.

A zone, 18.2-inches in diameter, and lying symmetrically about the axis at the bottom of the interior, is sphero-segmental in shape and is joined to the cylindrical portion by a surface with a radius of 8 inches, to correspond with similar surfaces cut in the breech of the casing and tube.

The exterior of the clamps is cylindrical over the seat of the charge, and is terminated at the rear by curved surfaces with radii of 32 inches and 11 inches (corners), which form the breech of the gun.

One clamp has a cylindrical lug at the center of the rear end, to form the seat for the firing pin, which is placed in the prolongation of the axis of the piece. A corresponding recess is cut in the other clamps.

The axial portion of the base of the clamps receives the pressure exerted upon the "cartridge head" in firing, and transmits it through the medium of the cylindrical walls of the clamps to the annular shoulders on the body of the cast-iron casing.

The cam lever.

This is pivoted beneath to the body of the gun and has two curved slots, or cams, one on each side of the pivot. Projecting pins screwed

into the body of the clamps engage these slots and act as bearing surfaces for the cam slots in opening and closing the breech mechanism. The lateral swing of the clamps is sufficient to uncover the rear end of the chamber and permit the insertion of the charge. The handle of this lever extends to the rear and is intended to be operated by one man.

The hammer.

This is pivoted to the rear of one of the breech clamps, and is designed to strike the firing pin for the purpose of exploding the .22 caliber pistol cartridge which ignites the charge and replaces the ordinary friction or electric primer. It is actuated by a lanyard.

The latch.

This is a hooked lever fastened to one clamp *above* the center of the breech and catches upon a pin in the other clamp when the mechanism is closed. It is retained in place by a flat steel spring.

The firing pin.

This is of sufficient size to cover the entire head of the pistol cartridge in firing and thus obviate the danger of misfires in side-primed cartridges. A slight beveled surface on the firing pin seat is so adjusted as to press the cartridge home in closing, in case it be not properly inserted, to avoid the danger of premature explosions while closing the breech mechanism.

The spiral firing-pin spring is intended to retract the point of the firing-pin and bring it flush with the interior face of the breech clamp after firing.

The cartridge head.

This is made of composition metal or bronze. It resembles a metallic cartridge case for small-arms in exterior form. The surface of the head is curved to correspond with the breech. The bottom on the interior is hemispherical, with a radius of 4 inches. It is pierced axially to receive the pistol cartridge for igniting the charge. The firing-pin hole is reinforced in rear by a steel bushing to prevent injury. This device forms the gas-check for the gun.

PRINCIPAL DIMENSIONS.

	Inches.
Total length of gun	168
Total length of bore	160
Length of rifled portion of bore	135.25
Diameter of bore	8
Chamber; diameter of, first, or forward cone: front base	8
rear base	8.19
first cylinder	8.19
second cone: front base	8.19
rear base	8.25
second cylinder	8.25
third cone: front base	8.25
rear base	8.67
counterbore	9.25
Chamber; length, first cone	1.6
first cylinder	1.45
second cone	1.5
second cylinder	8.5
third cone	11.25
counterbore	0.45

	Inches.
Total length of chamber	24.75
Tube; exterior diameter: front end	10.5
at shoulder	10.5
thickness of steel walls	1.25
cylindrical shoulder, exterior diameter	12.00
length	9.00
thickness of steel walls	1.875
Casing; diameter at muzzle: exterior	14.95
interior	10.5
thickness of walls	2.23
exterior diameter at seat of charge, top of shoulder	30.00
bottom of shoulder	28.00
total thickness of metal (iron and steel) at seat of charge	9.875
Breech clamps (two):	
Radius of base of breech (outside)	32.00
corners rounded, radius of	11.00
Radius of bottom of breech (inside)	34.00
corners rounded, radius	8.00
Thickness of metal at bottom	8.00
Cylindrical part, diameter; exterior	33.4
interior across shoulders	28.0
interior across grooves	30.0
thickness at shoulders	2.5
at first groove	1.53
at second groove	1.58
at third groove	1.75
Number of recoil shoulders (casing and clamps): Three each.	
Measured longitudinally:	
Length of groove in casing { at bottom	3.0
at top	4.0
clamps { at bottom	3.5
at top	4.5
Length of shoulder in casing { at top	3.0
at bottom	4.0
clamps { at top	2.5
at bottom	3.5
"Cartridge head," or loading tube:	
Exterior: total length	12.00
length of head, cylindrical part	0.45
base	0.30
length of body	11.25
diameter: front end	8.25
rear end	8.67
head	9.25
radius of base	34.0
Interior: total length	11.0
diameter, conical part: front base	8.05
rear base	8.0
radius of bottom	4.0
Thickness of metal: front end	0.10
at bottom (on axis)	1.0

WEIGHTS.

	Pounds.
Total weight of gun	18,540
Weight of clamps	3,452
Weight of "cartridge head," or loading case	48.5
Preponderance, muzzle	327

RIFLING.

This is polygroove, with an equal number of lands and grooves.

Number of grooves		45
Grooves, width	inch	0.3884
depth	do	0.06
bottom rounded with radius of	do	0.06
Lands, width	do	0.17
rounded with radius of	do	0.01
Twist, uniform, one turn in	feet	30

VENTING.

The vent is axial. The charge is ignited by a pistol-ball cartridge (caliber, .22-inch), seated in a steel bushing in the "cartridge head," or loading case. The cartridge is exploded by a blow from the firing-pin.

MARKS.

The marks on the muzzle are: "8″ Yates—S. B. I. W.—1884.—D. A. L.—wt. 18540 lbs." The tube has "Nashua steel" marked on the muzzle. The clamps have "Midvale steel" marked on each; and "Yates Patent, June 28, 1881" under the firing-pin seat.

PHYSICAL PROPERTIES.

Steel (Midvale) in the clamps.

The following data regarding this material was furnished by Colonel Yates:

Number of casting.	Elongation.	Elastic limit.	Tenacity.
	Per cent.	*Lbs. per sq. in.*	*Lbs. per sq. in.*
4176	6.5	41,750	83,500
4219	8.5	43,671	87,343

NASHUA STEEL TUBE.

Six specimens, marked, respectively, A, B, C, D, E, and F, have just been turned over by the South Boston Iron Works, who state that they are informed by the Nashua Steel Works that these specimens were taken from the upper end of the sinking head of the ingot from which the tube was made, and at distances from the center corresponding to the distances of the walls of the tube from that point. The specimens have been sent to the commanding officer of Watertown Arsenal.

Dimensions of specimens: Length, 5 inches, and 1.15 inches square.

REMARKS.

The first tube ordered for this gun was furnished by Firth, of England. The tube had sprung in tempering. An attempt was made to remedy the curvature and produce a straight bore. In doing this the caliber was increased so much that the inventor, Colonel Yates, rejected it for erroneous dimensions. The new tube was procured from the Nashua Steel Works and proved to be free from apparent cracks, flaws, and blow holes.

The first set of castings for clamps furnished by the Midvale Steel Works was rejected by Colonel Yates for defects of material. The second set from the same parties showed some defects, especially upon the exterior, most of which, however, would have been removed in turning had not a mistake been made in turning the interior out to a greater diameter by 0.9 of an inch, cutting out just so much of the soundest metal. To compensate for this error Colonel Yates directed that a greater thickness of metal be left on the exterior than originally intended. This change diminished the amount of metal to be taken from the outside, and the turning failed to remove the bad spots on the exterior.

BOSTON, MASS., *December* 31, 1884.

Report of inspection and proof of 8-inch Yates B. L. rifle No. 1, *converted from a* 10-*inch Rodman S. B. gun, at the South Boston Foundry, under contract dated September* 10, 1883.

Subject of measurement.	Dimensions. Prescribed.	Actual.	Actual variations.
	Inches.	*Inches.*	*Inches.*
Total length of gun	168.	168.	....
Total length of bore (and tube)	160.	160.	....
Length of rifled portion of bore	185.25	135.25	....
Total length of chamber	24.75	24.75	....
Diameter of bore	8.0	7.999	—.001
Chamber diameter:			
First cone, front base	8.0	8.000	....
rear base	8.19	....	....
First cylinder	8.19	8.254	+.064
Second cone, front base	8.19	8.254	+.064
rear base	8.25	8.254	+.004
Second cylinder	8.25	{ 8.254 8.252	{ +.004 +.002
Third cone, front base	8.25	8.252	+.002
rear base	8.67	8.64	—.03
Counterbore	9.25	9.24	—.01
Length:			
First cone	1.6	1.6	0
First cylinder	1.45	1.45	0 } Cylinder.
Second cone	1.5	1.5	0
Second cylinder	8 5	8.5	0
Third cone	11.25	11.25	0
Counterbore	0.45	0.45	0
Tube—exterior diameter—front end	10.5	10.494	—.006
at shoulder	10.5	10.497	—.003
thickness	1.25	1.249	—.001
Cylindrical shoulder—exterior diameter	12.0	11.919	—.001
length	9.0	9.000	0
thickness of walls	1.875	1.879	+.004
Extension piece, length	34.55	34.55	0
diameter, front end	14.95	14.95	0
rear end	17.84	17.84	0
length of screw-thread	8.00	8.00	0
pitch of screw	0.75	0.75	0
Play of tube	.003	.003	0
Casing, length	125.45	125.45	0
diameter, front shoulder	16.04	16.04	0
screw-thread	14.5	14.496	—.004
length of screw	8.03	8.03	0
pitch of screw*	0.75	0.75	0
counterbore-diameter	12.0	12.00	0
depth	9.0	9.00	0
Interior diameter of casing	10.5	10.497	—.003
Breech-clamps, weight of clamps:			
Total length	45.0	53.35	+8.35
Thickness of metal over grooves	1.5	{ 1st, =1.6 2d, =1.7 3d, =1.8	1st, +.1 2d, +.2 3d, +.3
over shoulders	1.75	{ 1st, =2.1 2d, =2.2 3d, =2.28	1st, +.35 2d, +.45 3d, +.53
Number of shoulders	8.	8.	0
Distance between faces	7.0	7.	0
Clearance	0.25	0.25	0
Total length of casing	160.	160.	0
Diameter of casing at seat of charge—top of shoulder†	30.	30.	0
bottom of shoulder	28.	27.975	—.025
Thickness of metal at seat of charge	9.875	9.875	0
Breech-clamps:			
Number	2.	2.	0
Length from pivot	50.40	50.40	0
Radius of outside, breech	32.0	32.0	0
inside	34.0	34.0	0
Thickness of metal at bottom	8.0	7.9	—.1
Radius of breech of gun-body	34.	34.	....
Corners rounded with radius of	8.	8.	....
Corresponding radius inside of clamps	34.	34.	....
Radius of breech of clamps	32.	32.	....
Corners rounded with radius of	11.	11.	....
Diameter of pivot bolt-holes in casing	2.56	2.56	....
Depth of	2.0	2.0	....
Distance from breech of casing	34.	34.	....

* Nine threads. † Diameter over third shoulder = 29.″9.

Report of inspection and proof of 8-inch Yates B. L. rifle No. 1, &c.—Continued.

Subject of measurement.	Dimensions.		
	Prescribed.	Actual.	Actual variations.
Pivot bolts:	*Inches.*	*Inches.*	*Inches.*
Length, total	6.75	6.75	
Diameter	2.55	2.55	
Length of thread	1.5	1.5	
Pitch of thread, per inch	6.	6.	
Cam-lever:			
Total length	47.	47.	
Distance pivot to handle	32.6	32.6	
cam-pins in slots	2.	2.	
Thickness	1.8	1.8	
Width	4.1	4.1	
Width slots	1.5	{ *1.6 †1.5 }	
Length clots chord	6.0	{ *6. †5.8	
Weight ... pounds	45.5	45.5	
Cam-pivot:			
Length, total	9.0	9.0	
Diameter	2.0	2.0	
Length of thread	1.7	1.7	
Pitch	6 to 1	6 to 1	
Number of washers	1	1.	
Diameter of washers	4.	4.	
Thickness of washers	0.5	0.5	
Latch:			
Length	10.7	10.7	
Diameter pivot-bolt	0.7	0.7	
Distance pivot-bolt from joint of clamps	1.7	1.7	
Diameter locking-bolt	0.75	0.75	
Distance from points of clamps	0.75	0.75	
Latch-spring:			
Length	6.3	6.3	
Bolt diameter	0.75	0.75	
Hammers:			
Diameter head	1.3	1.3	
face	0.625	0.625	
Length	2.25	2.25	
Distance head from pivot	4.	4.	
Distance end of lever-pivots	1.25	1.25	
Number of lands and grooves	45.	45.	
Twist, one turn in 30 feet			
Grooves:			
Width	0.3884	0.3884	
Depth	.06	.058	
Rounded with radius of	.06	.06	
Lands:			
Width	.17	.17	
Rounded with radius of	.01	.01	
"Cartridge-head"			
Total length	12.	12.	
Length of head, cylindrical point	0.45	0.45	
base	.03	.03	
Length of body	11.25	11.3	
Diameter, front end	8.25	8.25	
rear end	8.67	8.65	
head	9.25	9.25	
Radius of base	34.	34.	
Interior, total length	11.	11.	
Diameter conical front base	8.05	8.05	
rear base	8.	8.	
Radius of bottom	4.	4.	
Thickness of metal, front end	0.10	0.10	
at bottom	1.0	1.0	
Diameter of trunnions	10.	10.	
Distance of trunnions from muzzle			
Total length of gun with handle	187.5	187.5	
Weight of loading case ... pounds	48.5	48.5	
Weight of clamps ... do	3,452	3,452	
Weight of gun ... do		18,540	
Preponderance, muzzle ... do		327	
Firing-pin:			
Diameter { small end	0.27	0.27	
Diameter { large end	0.625	0.625	
Length	8.	8.	
Length of spring	3.2	3.2	
Diameter of hole for sleeve	0.625	0.625	
Diameter of thread	1.	1.	
Length of thread	1.5	1.5	
Pitch, threads per inch	8.	8 —	

* Front. † Rear.

Physical properties.

Specimen (Midvale steel).	Tenacity.	Elastic limit.	Elongation per inch at rupture.	Remarks.
			Per cent.	
Clamps:				
No. 4176	83, 500	41, 750	6. 5	Data furnished by Colonel Yates.
No. 4319	87, 343	43, 691	8. 5	

Tube: Nashua steel; six specimens sent to Watertown Arsenal this week.

I certify that the foregoing report is correct, and that the Yates 8-inch B. L. rifle therein specified has been accepted by me as conforming to the standards as to dimensions, quality of material, and character of workmanship prescribed by Colonel Yates, U. S. A.

December 31, 1884.

D. A. LYLE,
Captain of Ordnance, Inspector.

Record of measurements with star-gauge and calipers of 8-*inch Yates B. L. rifle (converted) No.* 1.

Distance from muzzle.	Diameter of bore of casing. Horizontal.	Diameter of bore of casing. Vertical.	Exterior diameter of tube.	Diameter of bore. Across lands.	Diameter of bore. Across grooves.	Distance from muzzle.	Diameter of bore of casing. Horizontal.	Diameter of bore of casing. Vertical.	Exterior diameter of tube.	Diameter of bore. Across lands.	Diameter of bore. Across grooves.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
*1	....	....	....	....	....	36	10. 499	10. 497	10. 494	7. 9995	8. 114
*2	....	....	....	....	....	37	10. 500	10. 497	10. 494	7. 999	8. 114
*3	....	....	....	....	....	38	10. 500	10. 498	10. 494	7. 999	8. 114
*4	....	....	....	....	....	39	10. 500	10. 498	10. 494	7. 999	8. 114
5	10. 499	10. 498	10. 489	8. 007	8. 112	40	10. 499	10. 498	10. 454	7. 999	8. 114
6	10. 499	10. 498	10. 494	8. 001	8. 112	41	10. 498	10. 498	10. 494	7. 999	8. 114
7	10. 498	10. 498	10. 492	8. 001	8. 112	42	10. 4975	10. 498	10. 493	7. 999	8. 114
8	10. 498	10. 498	10. 492	8. 001	8. 112	43	10. 4975	10. 498	10. 493	7. 998	8. 114
9	10. 498	10. 498	10. 494	8. 001	8. 112	44	10. 4975	10. 497	10. 494	7. 9985	8. 114
10	10. 4985	10. 498	10. 492	8. 0025	8. 112	45	10. 498	10. 497	10. 494	7. 998	8. 114
11	10. 498	10. 498	10. 494	8. 003	8. 112	46	10. 498	10. 497	10. 494	7. 998	8. 114
12	10. 499	10. 498	10. 494	8. 003	8. 112	47	19. 498	10. 497	10. 494	7. 9985	8. 114
13	10. 498	10. 498	10. 491	8. 002	8. 113	48	10. 498	10. 497	10. 494	7. 998	8. 114
14	10. 498	10. 498	10. 492	8. 001	8. 112	49	10. 4975	10. 497	10. 494	7. 998	8. 114
15	10. 498	10. 498	10. 492	8. 001	8. 112	50	10. 497	10. 497	10. 495	7. 998	8. 114
16	10. 498	10. 497	10. 491	8. 001	8. 112	51	10. 497	10. 497	10. 494	7. 998	8. 114
17	10. 498	10. 497	10. 492	8. 0015	8. 112	52	10. 497	10. 497	10. 494	7. 998	8. 115
18	10. 4975	10. 497	10. 494	8. 001	8. 113	53	10. 497	10. 497	10. 493	7. 998	8. 115
19	10. 497	10. 497	10. 492	8. 001	8. 112	54	10. 497	10. 4975	10. 494	7. 997	8. 115
20	10. 497	10. 496	10. 494	8. 001	8. 113	55	10. 497	10. 4975	10. 494	7. 998	8. 115
21	10. 497	10. 496	10. 594	8. 0005	8. 113	56	10. 497	10. 498	10. 494	7. 998	8. 114
22	10. 497	10. 496	10. 493	8. 001	8. 113	57	10. 497	10. 498	10. 494	7. 998	8. 114
23	10. 497	10. 497	10. 493	8. 0005	8. 113	58	10. 497	10. 497	10. 494	7. 998	8. 114
24	10. 497	10. 496	10. 494	8. 0005	8. 113	59	10. 497	10. 497	10. 494	7. 998	8. 114
25	10. 497	10. 496	10. 492	8. 0000	8. 113	60	10. 497	10. 497	10. 495	7. 9985	8. 114
26	10. 497	10. 495	10. 492	8. 0005	8. 1125	61	10. 497	10. 497	10. 495	7. 999	8. 114
27	10. 497	10. 495	10. 492	8. 0000	8. 113	62	10. 497	10. 497	10. 494	7. 9985	8. 114
28	10. 497	10. 495	10. 494	7. 9995	8. 113	63	10. 498	10. 497	10. 493	7. 998	8. 114
29	10. 496	10. 495	10. 494	8. 0000	8. 113	64	10. 497	10. 497	10. 494	7. 9985	8. 114
30	10. 497	10. 496	10. 494	8. 0000	8. 113	65	10. 497	10. 497	10. 494	7. 9985	8. 114
31	10. 497	10. 495	10. 492	7. 9995	8. 113	66	10. 497	10. 497	10. 494	7. 9985	8. 114
32	10. 498	10. 496	10. 494	8. 0005	8. 113	67	19. 497	10. 497	10. 494	7. 9985	8. 114
33	10. 497	10. 496	10. 492	8. 0000	8. 113	68	10. 497	10. 497	10. 494	7. 999	8. 114
34	10. 498	10. 498	10. 494	8. 0000	8. 113	69	10. 498	10. 497	10. 494	7. 999	8. 114
35	10. 498	10. 497	10. 494	7. 9995	8. 114	70	10. 498	10. 497	10. 494	7. 999	8. 114

* Muzzle of extension piece cut off flush with end of tube.

Record of measurements with star-gauge and calipers of 8-*inch Yates B. L. rifle* (*converted*) *No.* 1—Continued.

Distance from muzzle.	Diameter of bore of casing. Horizontal.	Diameter of bore of casing. Vertical.	Exterior diameter of tube.	Diameter of bore. Across lands.	Diameter of bore. Across grooves.	Distance from muzzle.	Diameter of bore of casing. Horizontal.	Diameter of bore of casing. Vertical.	Exterior diameter of tube.	Diameter of bore. Across lands.	Diameter of bore. Across grooves.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
71	10.497	10.497	19.493	7.9985	8.114	120	10.497	10.497	10.494	8.9995	8.1165
72	10.498	10.497	10.494	7.9985	8.1135	121	10.497	10.497	10.494	8.000	8.1165
73	10.498	10.497	10.494	7.999	8.1135	122	10.497	10.497	10.495	8.000	8.116
74	10.498	10.497	10.494	7.999	8.1135	123	10.497	10.497	10.494	7.9995	8.116
75	10.498	10.497	10.494	7.9985	8.113	124	10.497	10.498	10.494	7.999	8.116
76	10.498	10.497	10.494	7.999	8.113	125	10.4975	10.498	10.494	7.999	8.116
77	10.498	10.497	10.494	7.999	8.113	126	10.4975	10.498	10.494	7.999	8.116
78	10.498	10.497	10.494	7.999	8.113	127	10.4975	10.498	10.494	7.999	8.117
79	10.498	10.497	10.494	7.999	8.113	128	10.4975	10.498	10.494	7.9985	8.116
80	10.498	10.497	10.494	7.999	8.113	129	10.498	10.498	10.493	7.9985	8.116
81	10.498	10.497	10.494	7.9985	8.113	130	10.498	10.498	10.493	7.999	8.116
82	10.498	10.497	10.494	7.999	8.113	131	10.498	10.498	10.493	7.999	8.116
83	10.498	10.497	10.494	7.999	8.113	132	10.4985	10.498	10.493	7.9995	8.116
84	10.498	10.497	10.494	7.999	8.113	133	10.4985	10.498	10.493	7.999	8.116
85	10.498	10.497	10.494	7.999	8.113	134	10.498	10.498	10.494	7.999	8.115
86	10.498	10.497	10,494	7.999	8.113	135	10.499	10.298	10.494	8.000	8.116
87	10.497	10.497	10.494	7.999	8.113	136	10.498	10.498	10.494	8.000	....
88	10.498	10.497	19.494	7.999	8.113	137	10.498	10.498	10.493	....	....
89	10.498	10.497	10.494	7.999	8.113	138	10.498	10.498	10.494	8.254	....
90	10.498	10.497	10.494	7.999	8.113	139	10.498	10.498	10.493	8.254	....
91	10.497	10.497	10.493	7.999	8.113	140	10.498	10.497	10.493	8.254	....
92	10.497	10.497	10.494	7.999	8.113	141	10.498	10.497	10.493	8.254	....
93	10.498	10.497	10.493	7.999	8.114	142	10.498	10.497	10.493	8.254	....
94	10.498	10.497	10.493	7.999	8.114	143	10.498	10.497	10.494	8.252	....
95	10.498	10.497	10.494	7.999	8.114	144	10.498	10.497	10.494	8.252	....
96	10.4975	10.497	10.492	7.999	8.113	145	10.498	10.497	10.494	8.252	....
97	10.4975	10.497	10.494	7.999	8.113	146	10.4975	10.497	10.493	8.253	....
98	10.498	10.497	10.493	7.999	8.113	147	10.497	10.497	10.494	8.254	....
99	10.4975	10.497	10.493	7.9995	8.114	148	10.497	10.497	10.493	8.252	....
100	10.498	10.497	10.494	7.999	8.114	149	10.597	10.497	10.494	8.252	....
101	10.4975	10.497	10.494	7.999	8.114	150	10.497	10.4965	10.493	8.252	....
102	10.497	10.497	10.494	7.999	8.115	151	10.497	10.497	10.493	8.252	....
103	10.4965	10.498	10.493	7.999	8.115	152	10.497	10.497	10.493	8.252	....
104	10.497	10.498	10.494	7.999	8.115	153	10.497	10.497	10.494	8.252	....
105	10.497	10.4975	10.494	7.999	8.115	154	10.497	10.497	10.494	8.252	....
106	10.497	10.4975	10.493	7.999	8.115	155	10.497	10.4965	10.492	8.254	....
107	10.497	10.497	10.493	7.999	8.115	156	10.497	10.497	(†)	8.253	....
108	10.497	10.497	10.494	7.999	8.115	157	....	....	11.999	8.253	....
109	10.497	10.497	10.493	7.9995	8.115	158	....	....	11.998	8.249	....
110	10.497	10.497	10.494	7.999	8.115	158.50	....	....	....	8.249	....
111	10.497	10.497	10.493	8.000	8.115	159	....	....	11.999	....	....
112	10.497	10.497	10.492	8.000	8.115	160	....	....	11.999	....	....
113	10.497	10.497	10.493	8.000	8.116	161	....	....	12.000	....	....
114	10.497	10.497	10.494	7.9995	7.116	162	....	....	11.998	....	....
115	10.497	10.497	10.494	7.9995	8.116	163	....	....	11.998	....	....
116	10.497	10.497	10.494	8.000	8.116	164	....	....	12.000	....	....
117	10.497	10.497	10.494	7.999	8.116	165	....	....	11.999	....	....
118	10.497	10.497	10.493	7.999	8.1155	165.25 end of cylinder.					
119	10.497	10.497	10.493	7.9995	8.116						

† Shoulder can't take with calipers.

APPENDIX 20.

REPORT ON THE CONSTRUCTION OF A PROOF-CARRIAGE FOR A 10-INCH BREECH-LOADING STEEL RIFLE, WITH ATTACHMENTS FOR MOUNTING AN 8-INCH RIFLE, MADE AT THE WEST POINT FOUNDRY.

BY LIEUT. D. A. HOWARD, ORDNANCE DEPARTMENT.

(4 plates.)

This carriage was contracted for July 8, 1885, and it was completed and ready for final inspection February 10, 1886.

It was constructed in accordance with drawings and specifications furnished with the contract by the Chief of Ordnance, U. S. A. Some modifications were afterward authorized during the progress of the construction.

DESCRIPTION OF THE FINISHED CARRIAGE.

The cheeks of the top-carriage are each formed of two plates of $\frac{5}{8}$-inch shell-iron, riveted to a forged wrought-iron frame of rectangular cross-section 4 inches wide by 3 inches deep, which conforms generally to the outline of the cheek-plates, except in rear, where it is supplemented by a knee-piece, also of wrought-iron, 4 inches wide by 2 inches deep, and in front, where a re-entering angle forms a recess for the front wheels. The frame is strengthened by a vertical and a diagonal brace placed between the plates and terminating beneath the trunnion-bed.

The plates project beyond the re-entering angle, in front, inclosing the front wheels, and beyond the main frame, in rear, inclosing the rear wheels, which are also covered by the knee-piece.

The cheeks are connected by two vertical transoms, front and rear, and by a horizontal transom, or bottom plate, all of wrought-iron 1 inch thick.

The front and rear transoms have smithed flanges 4 inches wide on the sides and lower edge, which are secured to the cheeks and bottom plate by 1-inch bolts.

The bottom plate extends under the cheeks, and is fastened to their frames by $1\frac{1}{4}$-inch tap-bolts with countersunk heads. It is planed, for contact with the cheeks, yokes, and chassis-rails.

The trunnion-beds were forged roughly in the frames, and after the cheeks were assembled and the cap-squares fitted in place, were bored to receive the gun-rings, or trunnion bushings, principally by means of which the carriage is adapted for use with either the 10 or 8 inch gun.

The 10-inch gun rings, of forged steel, are of the same width as the trunnion-beds, and have a collar on the exterior cylindrical surface, fitting a corresponding groove in the cap-squares and trunnion-beds. The 8-inch gun-rings, of cast steel, are in part similar to the 10-inch rings,

but have in addition flanges 4 inches thick, to bear against the inner cheek-plates and the rim-bases of the smaller gun. They are bolted to the cheeks, and each is further supported by two removable wrought-iron braces bolted to the cheek; one a block resting on top of the front transom, and the other following the inside diagonal brace of the cheek along the exterior of the inner cheek-plate. The interior diameters of these rings are made 1 inch larger than the diameters of the trunnions of the corresponding guns as at present designed; the intention being to interpose a ring of soft metal one-half an inch thick.

The front wheels of wrought-iron are keyed to steel axles, the journals of which revolve in cylindrical bushings, also of wrought iron, with wide circular flanges and eccentric bore.

The eccentricity of the bore enables the bearing of the wheels on the rail to be adjusted by revolving the bushing through the proper angle.

The bushings are secured to the cheek-plates by tap-bolts through the flanges.

Each rear wheel revolves on an eccentric axle of steel, that passes through two bronze bushings fastened to the cheek-plates, and has a worm-wheel keyed to its projecting outer arm. The axle revolves only when operated by the worm-gear.

THE WORM-GEAR.

A worm-gear is attached to the rear end of each cheek. It consists of the worm-wheel already mentioned, which is operated by a worm of 3¼ inch pitch diameter, and 1-inch pitch, cut on a steel shaft, that carries a 12-inch hand-wheel of bronze, and is supported by bronze bearings bolted to the cheek. The eccentric arm of the axle is 1 inch long, and the throw of the eccentric is consequently 2 inches; and as the bushings are so set in the cheeks that when the center of the eccentric, which is centered in the wheel, is in its highest position relative to the center of the axle, the wheel clears the chassis-rail by ¼ of an inch; then, when in its lowest relative position, the rear part of the carriage is lifted 1¾ inches; but from the nature of the gearing it may, of course, be held fixed in any intermediate position.

The amount of clearance given these wheels is important as affecting the length of sliding friction during recoil.

THE ELEVATING GEAR.

Each cheek is provided with a spur-gearing, which comprises a 2-inch steel shaft with a wrought-iron hand-wheel and clamp on its outer and a bronze pinion on its inner arm, a 2.5-inch intermediate shaft of steel, with a spur-wheel on its inner and a pinion on its outer arm, and a 3-inch steel shaft, with a spur-wheel on its outer and the rack-pinion on its inner arm. This pinion, with the 10-inch gun mounted, gears in a curved rack with teeth on its concave edge. The rack pivots on a bronze trunnion, to be attached to the gun, and is held in place engaged with the teeth of the pinion by a steel roll that bears against its convex plain edge. The roll is supported by a stud passed through the cheek. The hand-wheel clamp is used to press the hub of the hand-wheel against the flange of the bushing, and the friction due to this pressure holds the wheels in position and the gun at the corresponding elevation.

The geared wheels and racks are all of bronze and the shafts all pass through bronze bushings set in the cheeks.

For use with the 8-inch gun mounted, two additional racks, with teeth on their convex edges, are provided, and as they will be at a greater distance from the cheeks with the smaller gun mounted, two longer rack-pinion shafts with longer bushings, two intermediate shafts with steel friction-rolls on their projecting inner arms, and two smaller bronze trunnions with bolts and washers to prevent the racks from slipping off, are also provided. The concave plain edges of these racks bear against the rolls on the intermediate shafts, and the rolls on the studs are not used. The other parts are used as with the 10-inch gun. Of the remaining component parts of the top-carriage, the front buffer plate is a heavy L bar, bolted to the upper side of the bottom plate at its front edge. The rear guides, of angle iron, about 6 inches long, are bolted to the bottom plate under the rear transom, with a play of one thirty-second of an inch between the inner flanges of the chassis-rail, and clearing the rear buffer transom by about half an inch when the top-carriage is in its position in battery. The outer cross-head yoke pieces, which are bolted to the bottom plate, serve as guides for the front part of the top-carriage, a rabbet being planed in the edge for a length of 3 inches to receive the inner flange of the chassis-rail, and from this point a bevel extends to the rear end of the yoke piece, where the depth of the cut is 2.05 inches, to allow sufficient play when the rear of the carriage rises on the counter-rails.

The forms and principal dimensions of the different parts of the top carriage are shown on Plate III.

THE CHASSIS.

The rails, or sides of the chassis are "built-up" beams, each formed bottom, with seven inside braces of varying lengths, corresponding to of two $\frac{5}{8}$-inch plates of shell iron riveted to two heavy T-pieces, top and the slope of 4° of the top T-piece, which, except the two end ones, are set perpendicular to that piece.

The rails or sides are connected primarily by the front and rear transoms, and secondarily by the front and rear buffer-transoms, the pintle transom, and cylinder-straps, all of wrought iron. The front transom, 1 inch thick, has smithed flanges bolted to the rails.

The rear transom, 2 inches thick, is riveted to angle irons that are bolted to the rails.

The front buffer transom, of L cross-section, extends across the front end of the chassis, is bolted to the top T-pieces, and has four rubber buffers attached to its upright flange. This flange is cut away over the rails, and the horizontal one is beveled to clear the front wheels of the top-carriage.

The rear buffer transom extends across the chassis 110.75 inches from the front end, measured along the top of the rail. Its buffers limit the recoil of the top-carriage by checking the backward motion of the rear buffer-plate, attached to the yokes, which comes in contact with them. They are four in number, are made of rubber, and are attached to the vertical flange of the transom, arranged so as to clear the piston-rods. As this flange extends downwards they are below the tops of the rails.

The horizontal flange of the transom is prolonged across the rails; it is set into the top T-pieces flush with their upper surfaces, and is bolted to their webs, the flanges having been cut away to permit this. The part of this flange included between the rails is planed off slightly to insure proper clearance for the bottom plate during the recoil.

The pintle transom, 2 inches thick in the middle portion, and 1 inch thick under the rails, with intermediate bevels, extends across the front part of the chassis, and is bolted to the under side of the bottom T-pieces. The middle part is planed to bear on the pintle-center, and has a hole drilled through it to admit the pintle-pin.

The cylinder-strap is composed of two parts, upper and lower, each forged with two corresponding semi-cylindrical portions and end flanges, with intervening plane portions. These two parts being fitted together, the cylinders thus formed were bored to fit accurately over the hydraulic cylinders between the collars on their front ends.

The rails are each supported at the ends by the front and rear wheels and intermediately by a bolster and screw.

The front and rear wheels, of wrought iron, revolve on feathered steel pins passed through holes in wrought-iron forks; the forks for the front wheels being bolted through the pintle-transom to the bottom of the rails; those for the rear wheels are bolted to the bottom of the rails and are shaped askew to cause the wheels to follow the rear traverse-circle.

The bolsters, of wrought iron, are bolted to the bottom T-pieces, and are each tapped for a ratchet-threaded screw. This screw, of steel, has a capstan head, and is inserted from below so that its head may rest on a traverse-cirele.

The counter-rails, of wrought iron, are wedge-shaped pieces notched into and bolted to the upper sides of the top T-pieces. They extend from a short distance in rear of the top-carriage in battery with an upward rise to the rear, nearly to the ends of the rails.

THE HYDRAULIC CYLINDERS.

The hydraulic cylinders, of gun steel with bronze heads, lie between the rails of the chassis, below and parallel to the top T-piece, and are in rear of the position of the top-carriage in battery. They are supported in front by the cylinder-strap, and in rear by bolts passing through the rear transom and holes in flanges on their rear heads.

The front heads are bolted to the faces of the cylinders, project slightly into the bore, and have stuffing boxes and glands similar to those of steam-cylinders. The rear heads are caps screwed on to the cylinders and packed to prevent leakage. The front heads were not packed, as they will have to be removed in order to drill holes for the passage of the oil through the pistons. For the same reason no packing was placed in the stuffing-boxes.

The front heads can be taken off without removing the cylinders, but unscrewing the rear heads will at least require the removal of the upper part of the cylinder-strap and the bolts through the rear transom, or the removal of the rear transom and the same bolts.

It would facilitate the removal of the transom if the inside heads of the rivets through the rail-plates, in the rear of it, were countersunk. The removal of the upper part of the cylinder-strap would be facilitated by cutting away the inner flange of the top T-piece of the rail and prolonging the plate flange of this part of the strap till it is flush with the upper surface of the rail. The cylinders internally are 72″.5 long and 8″ in diameter. The pistons, of wrought iron, are 7″.98 in diameter, and are to have holes drilled through them to modify the resistance which the oil in the cylinders will offer to their motion.

The piston-rods, of machinery steel, screw into the pistons and are secured by nuts. The rods pass out through the front heads and stuff-

ing-boxes, and their forward ends screw into wrought iron cross-heads that are each embraced by two wrought iron yoke-pieces bolted to the bottom plate of the top-carriage. A steel pin is passed from without inward through holes in each pair of yoke-pieces and through the embraced cross-head with a play of 0.2 of an inch in the latter, to prevent any bending of the piston-rods when the rear of the carriage rises on the counter-rail, but with no play in the former holes. In order to assemble these pieces with the yokes bolted to the bottom plate, a hole 5.5 inches in diameter is drilled in each rail, through which and the holes in the yokes and cross-heads the pin may be passed, when the yokes have been brought into proper position.

These two holes in the rails are closed by accurately fitted bronze plugs, that serve also to strengthen the chassis.

THE HOISTING-APPARATUS.

This comprises a crane, crane-bracket, bevel-gear, and differential pulley. The crane-bracket is bolted to the outside of the left rail of the chassis in a position to be nearly opposite the breech of the gun when it is mounted.

The crane is supported by the bracket and is revolved by a bevel-gear operated by a crank. The differential pulley is attached to its hooked end by a link.

The forms and principal dimensions of all the parts of the chassis and hydraulic cylinders are shown on Plate II.

THE PLATFORMS AND STEPS.

The platforms and steps are all attached to the chassis and are made of No. 5 wire woven, with ¾-inch mesh, in light wrought-irom frames that are riveted to similar outside frames. Two steps in rear are supported by angle irons shaped for this purpose and bolted to the rear transom; two steps and a small platform are similarly attached to the right rail; and a large platform rests on angle irons that are fitted over the hydraulic cylinders and secured to them by curved straps of wrought iron. It also rests on two brackets, bolted to the inside plates of the rails, near its front end, and it is bolted to these brackets and angle irons by rose-headed bolts passed through the meshes. The positions of the platforms and steps are shown on Plate I, and the positions, dimensions, and details of the fastenings are shown on Plate IV.

THE PINTLE-CENTER.

The pintle-center is made of cast iron, with a wrought-iron ring shrunk around the bearing surface for the pintle-transom. It is cylindrical, with a wide, horizontal flange that is circular in front and rectangular in rear, and is strengthened by seven vertical webs.

The cylinder was cast hollow and bored to receive the wrought-iron pintle-pin. It extends below the flange to be let into the foundation. The pintle-pin is held in place by a taper pin of steel. The pintle-center or plate is shown on Plate II.

WEIGHT OF THE CARRIAGE.

	Pounds.
Weight of top-carriage and gearing	12,389
Weight of chassis, including yokes	22,344
Weight of pintle-center and pins	2,594
Total weight	37,327

FABRICATION.

The materials used in the construction of the carriage, consisting of forgings, castings, and rolled plates, were all furnished and the machining was all done by the West Point Foundry Association.

The large wrought-iron forgings and rolled plates were obtained from the Paterson Iron Works.

The steel forgings for the hydraulic cylinders and 10-inch-gun rings and the steel castings for the 8-inch gun rings were obtained from the Midvale Steel Works. All the bronze castings, the small steel and wrought-iron forgings, and the iron casting for the pintle-center were fashioned at the West Point Foundry.

The principal machining operations required for reducing the material to prescribed dimensions were turning, boring, planing, and drilling.

All contact surfaces are planed or faced to obtain an even bearing, and the bolster-screws and all shafts, axles, pins, bushings, and wheels, except hand-wheels, are machine finished throughout.

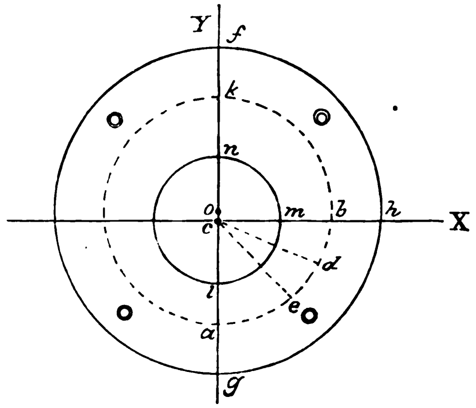
Nothing of special interest occurred in the machining of the different parts.

The bushings of the rear wheels of the top-carriage were set in the cheeks so as to give the rear wheels a maximum clearance of one-fourth of an inch, as prescribed. With this clearance they strike the counter-rails and begin to roll at 3.6 inches from the front ends of these rails.

As the top-carriage is intended to start on sliding friction during the recoil, the front wheels should have a very light bearing, or a very small clearance, so that they will not be brought to a full bearing until the rear wheels have begun to roll on the counter-rails, and the rear of the carriage is slightly lifted, owing to the ascent of the inclined plane.

Authority was given to set the centers of the bushings of these wheels lower than was at first prescribed, and they were set 7.3 inches above the lower edge of the bottom plate, with the center of the bushing directly above the center of the base of the eccentric bore; the center of the axle is 0.35 of an inch lower, and as the radius of each wheel is 7 inches, this causes the wheels to project 0.05 of an inch below the bottom plate, which will allow for any change of form or "spring" in the frame due to the weight of the gun when mounted.

However, whether this change occurs or not, the bearing, or clearance, of the wheel can be easily regulated by revolving the eccentric bushing as is shown by the following diagram:



ghf is the circumference of flange. *abk* is the circumference of base of cylindrical part of bushing. *abk* and *ghf* are concentric, with center at *o*. Throw of eccentric=2oc=0''.70. *lmn* is the circumference of base of eccentric cylindrical bore. *oc*=eccentricity=0.35 of an inch. *ln*=5''.02 and *ak*=8''.5 are the diameters of cylindrical bore and of cylindrical part of bushing, respectively. The latter cylinder being fitted in the holes in the cheek plates, the revolution takes place about its axis through *o*, and the locus of *c* will be a circumference whose center is *o*; *c* and *o* are the centers set as prescribed. To find the distances through which the center *c* of the wheel axle is lifted by revolving the bushing until *ce*, *cd*, and *cb* become successively vertical, it is only necessary to find the quantities *ce*—*ca*, *cd*—*ca* and *cb*—*ca*. *ca*=*oa*—*oc*=4.25—0.35=3.95. *oa* being equal to *ak*÷2=8.5÷2=4.25.

The equation of the circle *abk* referred to the rectangular co-ordinate axes *c*X and *c*Y is $x^2+(y-.35)^2=(4.25)^2$, derived from the general equation $(x-x')^2+(y-y')^2=R^2$, in which $x'=o$ $y'=.35$ and R=4.25 for the circle considered. Making $y=o$ in the equation deduced, $x=4.23+$ which corresponds to a revolution of 90° and since *cb*—*ca*=4.23—3.95=0.28 the center of the wheel has been lifted 0''.28 and the clearance of the wheel should be 0.28—0''.05=0''.23.

By changing the reference first to *cd* and then to *ce* as new axes of X it may be shown in a similar manner or by trigonometry, that the quantity *cd*—*ca*=4''.14—3''.95=0''.19 and that *ce*—*ca*=4''.00—3''.95=0''.05, or that when the bushing is revolved 72°, until *cd* is vertical, the center of the wheel has been lifted 0''.19 above its primitive position, and when it is revolved 48½°, until *ce* is vertical, this center has been lifted 0''.05. This last position would be practically attained by a revolution of about 45° and would just bring the wheels to a bearing should no change of form take place in the frame when the gun is mounted.

If after such revolution the diameters of the wheels should be reduced by wear, the bearing could be readjusted by counter-revolution. This will, of course, apply to the case of unequal wear.

Any amount of revolution not a multiple of 90° will require new bolt-holes to be tapped in the check-plates, or, if more desirable, drilled in the bushing-flange. A revolution of 90° will simply change the mating of the holes in the flanges and plates.

CHANGES MADE DURING THE FABRICATION.

In the original designs the material for the hydraulic cylinders was a composition of 65 parts copper, 32.5 parts zinc, and 2.5 parts tin, but they were afterwards authorized to be made of Midvale steel tubes.

Two steel tubes which were made by the Midvale Steel Company for 8-inch converted guns were used. These had been rejecteed as gun tubes on account of local defects in the breech end, but the muzzle ends were used and the finished cylinders show no defects whatever. The original lengths of the tubes were over 120 inches, of which 73 inches, beginning at the muzzle end, was cut off of each for use.

The dimensions remain the same as designed for the composition cylinders, except that the diameters of the collars are 13.3 instead of 13.5 inches.

The heads were to have been made of the same composition, but were subsequently authorized to be made of gun-bronze. In the mean time several attempts were made to obtain sound castings of the composition for the rear cylinder heads, but all the castings were defective at the junction of the cylindrical and flat portions. Authority having been

given to make tests of the tensile strength of this metal, two tensile test specimens were cut longitudinally from the sound cylindrical part.

These specimens were tested November 28, 1885, on the testing-machine at the West Point Foundry, with the following results:

The first specimen was loaded with an initial weight of 20,000 pounds per square inch, and broke below. Second specimen: Initial weight, 10,000 pounds; breaking weight, 11,800 pounds; and the tenacity, 23,600 pounds.

Diameter of specimens before test .... inch..	0.797
Length of specimens between shoulders before test .... inches..	2.60
Specific gravity of specimens	8.3958
Diameter of second specimen after test .... inch..	0.788
Length of second specimen between shoulders after test .... inches..	2.65

Both fractures showed that the casting was not homogeneous, and the poor success attained may have been due to a lack of practical acquaintance with this particular mixture; but unless further experience would develop better results, the several failures to obtain sound castings and the low tensile strength of the specimens would indicate that this composition cannot be advantageously used for similar purposes in future.

All the geared wheels, racks, rack-trunnions, and bushings, except front-wheel bushings, are made of bronze castings. The teeth of the wheels were milled; those of the racks were cast, and subsequently planed and file-finished.

The authorized changes made in the dimensions shown in the original designs relate chiefly to the bolster and screw, crane, braces for 8-inch gun, front transom, and buffer-spindles.

DRAWINGS.

The accompanying drawings are modified copies of those furnished with the contract from the Ordnance Office, the modifications including all the changes made during the manufacture, so that these drawings show the carriage and its parts as they were finished.

Plate I shows the side and rear elevations and plan of the carriage assembled; the elevations with the 10-inch and 8-inch guns mounted; the plan with these guns removed.

Plates II, III, and IV have already been explained. The parts shown on these three are drawn to different scales; but no confusion need arise from this fact, as the principal dimensions are all marked in inches and the scales are not necessary.

The dimensions as marked do not show the slight variations from those prescribed, determined by measurement of the different parts. In two or three cases where the variation was readily appreciable, but did not affect the utility of the part, the true dimensions are noted.

Where the material of which the part is made is not put down, it is wrought iron.

The special bolts and rivet-heads are shown on Plate III in form and dimensions.

INSPECTION.

The principal dimensions of the individual parts were measured, as soon as completed and ready for assembling, with greater or less precision, according to their functions in the structure; and where the variation from the prescribed dimensions was sufficient to impair the usefulness of the part it was rejected. Two bolsters and one bronze rack-trunnion were thus rejected.

Also such pieces as were manifestly unsound and which it was believed might prove a source of weakness were rejected. In the final inspection of the finished carriage the following points were observed concerning the working parts:

I.—That the top carriage could be moved back on the chassis until the rear buffer-plate came sharply in contact with the rear buffers, without hitch or undue stiffness in the working of any of the parts brought into play.

This was also considered a practical test of the parallelism of the cylinders, since the pistons were thus moved simultaneously through the cylinders, as were the piston rods through the closely-fitting glands and front heads, all working smoothly.

II.—That the rear wheels having been set with their maximum clearance, when the top carriage reached its extreme rear position it could still be lifted through nearly the full throw of the eccentric, by means of the worm-gears, before the bevel of the guides on the yokes came in contact with the lower side of the flange on the chassis rail.

III.—That when the top carriage was then allowed to run forward to its position in battery, with the front buffer-plate bearing against the front buffers, there was a clearance of nearly half an inch between the fronts of the rear guides and the rear buffer-transom, which allows for that amount of compression of the front buffers before the guides could strike the transom. Part of this clearance was obtained by cutting away the fronts of the guides slightly.

IV.—That the worm-gears turned the rear-wheel axles properly through a complete revolution.

V.—That the trains of wheels for elevating and depressing were set to gear smoothly.

VI.—That when the top carriage was drawn back the rear guides cleared the platform over the cylinders.

VII.—That the buffer-plates struck the buffers evenly.

VIII.—That the crane could be readily revolved by its bevel-gear, with a weight of about 600 pounds attached to the differential pulley, and hoisted to the level of the trunnion-beds; this weight being approximately that of the heaviest 10-inch projectiles.

IX.—That the maximum clearance of each rear wheel was one-fourth of an inch, and that the wheel set with this clearance struck the counter rails, and began to roll at the same time, the points of first contact being about 3.6 inches from the front ends of these rails, measured along the chassis rail. This, supposing the front wheels to be set without clearance, makes the maximum length of sliding friction during the recoil about 13 inches, as the centers of the rear wheels are about 9.5 inches, in front of the ends of the counter rails, measured as above; but this last distance varies for other positions of the eccentric. By changing the clearance of the rear wheels the length of sliding friction can be fixed anywhere between 13 and about 9.5 inches, after which any further change would bring these wheels to a bearing, and the carriage would start on rolling friction.

If the front wheels have clearance the length of sliding friction will depend upon its amount and that of the rear wheels, as the carriage will move on sliding friction, meaning by this partly sliding and partly rolling friction, since the rear wheels may be rolling, until the rear wheels have risen a sufficient distance on the counter rails to bring the front wheels to a full bearing.

The rise of the counter rails from the chassis rail will form part of the data for computing the length of sliding friction for any fixed

amounts of clearance for the front and rear wheels. This rise is 4.625 inches in 66 inches, or 0.07 of an inch per inch.

When the rear wheels rise on the counter-rails the top-carriage will rotate about the bearing edge of the slight bevel at the front end of the bottom plate until the front wheels are brought to a bearing, and to determine the height through which the rear wheels have risen, form the proportion*.

Actual distance from lowest point of front wheel to axis of rotation : Distance from point of contact of rear wheel to axis of rotation :: Clearance of front wheel : Height through which rear wheel has risen.

From which, the first three being known, the fourth is deduced. This result, expressed in inches, divided by 0.07, will be the distance the rear wheels have moved along the counter-rails in the direction of the chassis-rail, which, added to 9.5 inches, previously referred to, will be the length of sliding friction corresponding to the assumed clearance, provided the rear wheels have none; if they have, divide it, expressed in inches, by 0.07, and add the quotient to the result just obtained for the total sliding friction.

In this case the second term of the above proportion should be, "Distance from lowest point of rear wheel to axis of rotation, measured along chassis-rail." To facilitate the assembling, all keys and bolts necessarily removed in taking the carriage apart have numbers stamped on them, and corresponding numbers are stamped on the wheels, axles, or other parts to which they belong.

Holes are drilled in the rear wheels of the chassis for the insertion of handspikes in traversing. Appended to this report are tables showing the principal dimensions of the carriage assembled, the principal dimensions, prescribed and actual, of the component parts of the carriage, the weights of the carriage and of some of its parts, and a list of the bolts and rivets used.

Date of final inspection, February 10, 1886.

PRINCIPAL DIMENSIONS OF CARRIAGE ASSEMBLED.

	Inches.
Length of chassis	219.1
Length of top of chassis-rail	219.75
Length of bottom of chassis-rail	213
Depth of chassis-rail in front	14
Depth of chassis-rail in rear	29.5
Top of chassis rail above ground-line (front)	32
Top of chassis-rail above ground-line (rear)	47.25
Total width of chassis	57.2
Width between inner flanges of rails (top)	40.2
Width between inner flanges of rails (bottom)	38.7
†Distance between rear buffer-plate and rear buffers when top-carriage is in battery	58
Length of top-carriage	136
Total width of top-carriage	52.7
Width of top-carriage between cheeks	42.2
Width between flanges of 8-inch-gun rings	34.2
Centers of gun-rings above chassis-rail	48
Centers of gun-rings above ground-line	80.9

Inclination of top-carriage to top of chassis-rail when in extreme rear position:

1. With rear wheels at maximum clearance	1° 37′
2. With rear wheels with centers down	2° 29′
Slope of top of chassis-rail	4° 2′

*This proportion is not obtained directly, but is easily deduced.

†Total length of recoil.

Table showing weights of carriage and of some of its principal parts.

No.	Names of parts weighed.	Weight.	Remarks.
		Pounds.	
1	Top-carriage, complete	12,389	Includes 8 and 10 inch gear.
1	Chassis, complete	22,344	
1	Pintle center, complete	2,594	
1	Carriage, complete	37,327	Includes 8 and 10 inch gear.
1	Front-wheel fork and pin	261	
1	Front wheel, chassis	173	
1	Rear transom, top-carriage	183	
1	Front transom, top-carriage	407	
1	Front wheel and axle, top-carriage	166	
1	Hand wheel, elevating-gear	58	
1	Hand-wheel shaft and clamp	28	
1	Rear buffer plate	136	
1	Intermediate shaft with spur-wheel and pinion	76	
1	Rack-pinion shaft with spur-wheel	99	
1	Stud and roll for 10-inch gun	21	
1	Worm-shaft with hand-wheel and bearings	55	
1	Eccentric-axle and worm-wheel	59	
1	Front-axle bushing	33	
1	Buffer-spindle	16	
1	Differential pulley and chain	42	
1	Crane	312	
1	Crane-gear, axle and crank	50	
2	8-inch-gun-rings, cast steel	1,063	Average weight, each 531.5.
2	Rack-pinion shafts, 8-inch gun	50	Average weight, each 25.
2	Intermediate shafts with rolls, 8-inch gun	56	Average weight, each 28.
2	8-inch-gun rack-trunnions	49	Average weight, each 24.5.
2	Rack-pinion shaft bushings, 8-inch gun	40	Average weight, each 20.
2	Intermediate shafts with spur-wheel and pinion	151	Average weight, each 75.5
2	Rack-pinion shafts with spur-wheel and pinion	248	Average weight, each 124.
2	10-inch-gun rack-trunnions	73	Average weight, each 36.5.
2	Elevating-gear racks, 10-inch gun	149	Average weight, each 74.5.
2	Elevating-gear racks, 8-inch gun	131	Average weight, each 65.5.
2	Hand-wheels with pinion, shaft, and clamp	171	Average weight, each 85.5.
2	10-inch gun rings	214	Average weight, each 107.
2	Worm-wheels with shaft, hand-wheel and bearings	167	Average weight, each 83.5.
1	Rack pinion	27	
1	Top-carriage, with 8-inch gun-rings and braces, front and rear wheels, and all bushings, but without elevating and worm gears.	10,840	
1	Top-carriage, complete for 8-inch gun	11,807	Deduced from table.

List of bolts and rivets.

Nature.	Number.	Length.	Diameter.	Remarks.
		Inches.	*Inches.*	
Special bolts	36	4.6	1	Wheel-forks, bolster, and pintle-plate to chassis rail.
Do	8	6.1	1	Do.
Ordinary bolts	2	5.25	1	Yokes to bottom plate of top-carriage.
Do	2	6.25	1	Do.
Do	6	3.75	1	Do.
Do	8	4.75	1	Do.
Do	2	5.75	1	Do.
Do	2	3.75	1	Front buffer-plate to bottom plate.
Do	2	3.25	1	Front transom to bottom plate.
Do	12	3.875	1	Yokes to angle-iron of buffer-plate.
Do	6	7.5	1	Front transom to chassis.
Do	6	7.25	1	Rear buffer-transom to chassis.
Do	12	7.25	1	Rear transom to chassis.
Do	8	7.5	1	Cylinder-strap to chassis.
Do	6	7.5	1	Cylinder-strap to chassis, countersunk heads.
Do	1	6.75	1	Do.
Do	8	7.5	1	Rear transom to top-carriage.
Do	5	3.0	1	Do.
Do	10	7.5	1	Front transom to top-carriage.
Do	8	7.75	1	Braces, 8-inch rifle, to top-carriage.
Do	4	10	1	Do.
Do	14	9.75	1	8-inch-gun ring to trunnion-bed.
Tap-bolts	8	3.5	1	Front buffer-transom to chassis.
Do	4	3.5	1	Front buffer-transom to chassis, countersunk heads.
Do	2	4	1.25	Front wheel-forks to chassis.
Do	4	5	1.5	Front wheel-forks to chassis, countersunk heads.
Do	10	Various	1.25	Counter-rails to chassis, countersunk heads.
Do	4	1.5	0.75	Do.
Do	30	3.5	1.25	Bottom plate to check-frame, countersunk heads.
Do	2	2	1	Rear guides to bottom plate, countersunk heads.
Do	16	1.625	0.75	Rear-wheel bushings to top-carriage, countersunk heads.
Do	16	1.625	1	Front-wheel bushings to top-carriage, countersunk heads.
Do	32	1.375	0.75	Shaft bushings to top-carriage, countersunk heads.
Do	8	1.5	0.75	Worm-bearings to top-carriage.
Do	2	3	1.25	Rear-wheel forks to chassis.
Rivets	211	5.25	0.875	Plates of top-carriage and chassis.
Do	6	5.25	0.875	Plates of top-carriage, countersunk heads.
Do	1	6.25	0.875	Plates of chassis and cylinder-strap.
Do	12	3.75	0.875	Angle-irons to rear transom.
Do	12	3	0.875	Angle-irons to buffer-plate.
Do	4	3	0.875	Angle-irons to rear buffer-transom.
Do	12	5.25	0.75	Plates of top-carriage and knee-pieces.
Steel tap-bolts	4	9.25	1	Through cap square bolts.

Table of principal dimen

Subject of measurement.	Total length.		Total thickness.		Total width.		Total depth.		Diameter.		Diameter of flange.	
	Prescribed.	Actual.	Prescribed.	Actual.	Prescribed.	Actual.	Prescribed.	Actual.	Prescribed.	Actual.	Prescribed.	Actual.
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
Front transom, top-carriage	......	......	1.0	1.1	42.2	42.2	30.3	30.3	......	......	......	......
Rear transom, top-carriage	......	......	1.0	1.2	42.2	42.2	17.0	17.0	......	......	......	......
Front buffer plate	38.0	38.0	1.5	1.65	5.5	5.5	5.75	5.75	......	......	......	......
Rear buffer plate	38.0	38.0	1.5	1.5	......	......	9.0	9.0	......	......	......	......
Counter rail, right	66.0	65.9	......	......	6.25	6.28	4.625	4.60	......	......	......	......
Counter rail, left	66.0	65.9	......	......	6.25	6.25	4.625	4.625	......	......	......	......
Rear transom, chassis	......	......	2.0	2.0	42.2	42.2	27.125	27.0	......	......	......	......
Front transom, chassis	......	......	1.0	1.0	42.2	42.2	12.5	12.4	......	......	......	......
Pintle transom, chassis	30.0	30.0	2.0 1.5 1.0	2.0 1.5 1.0	57.2	57.3	......	......	......	......	......	......
Rear buffer transom	8.0	8.0	2.0	2.2	52.7	52.7	8.75	8.75	......	......	......	......
Front buffer transom	11.0	11.0	1.5	1.5	52.7	52.65	7.5	7.5	......	......	......	......
Bottom plate	104.0	104.0	1.0	1.1	52.7	52.67	......	......	......	......	......	......
Cylinder strap	10.0	10.0	1.0	1.05	42.2	42.15	21.75	21.7	13.5	13.6	......	......
Piston rods, two	120	120	......	......	......	......	......	......	3.25	3.25	......	......
Cross-heads, two	10.75	10.75	5.47	5.47	......	......	......	......	......	......	......	......
Pistons, two	......	......	3.0	3.0	......	......	......	......	7.98	7.98	......	......
Bolsters, two	......	......	9.0	9.0	7.25	7.25	11.0	11.0	Bot. 7.0	7.0	......	......
Bolster screws, two	14.0	14.0	......	......	......	......	......	......	Head. 7.0	7.0	......	......
Hydraulic cylinder, right	72.5	72.5	1.75	1.75	......	......	......	......	11.5	11.5	Collars. 13.5	13.3
Hydraulic cylinder, left	72.5	72.5	1.75	1.75	......	......	......	......	11.5	11.5	Collars. 13.5	13.3
Cylinder heads, rear	8.0	8.0	1.25	1.25	......	......	......	......	14.0	14.0	....	......
Cylinder heads, front	7.0	7.0	......	......	......	......	......	......	7.25	7.25	13.5 10.0	13.3 10.0
Glands, two	5.0	5.0	......	......	......	......	......	......	5.25	5.25	......	......
Crane bracket	7.25	7.25	......	......	19.0	19.0	22.25	22.25	......	......	......	......
Hand-wheels, two	......	......	......	......	......	......	......	......	35.0	35.0	Hub. 5.5	5.5
10-inch gun rings, two	......	......	......	......	5.25	5.25	......	......	16.0	16.0	......	......
8-inch gun rings, two	......	......	......	......	9.25	9.25	......	......	16.0	16.0	23.0	23.0
Cross-head yokes, outside	27.5	27.5	2.0	2.0	8.375	8.375	12.5	12.5	......	......	......	......
Cross-head yokes, inside	27.5	27.5	2.0	2.0	6.75	6.75	12.5	12.5	......	......	......	......
Yoke pins, two	12.0	12.0	......	......	......	......	......	......	3.0	3.0	......	......
Rear wheels, chassis, two		......	4.75	4.78	......	......	......	......	17.0	17.0	......	......
Front wheels, chassis, two		..	4.4	4.4	......	......	......	......	14.0	14.0	......	......
Rear-wheel forks, two	13.0	13.0	2.0	2.0	9.75	9.72	12.25	12.25	......	......	......	......
Front-wheel forks, two	20.0	20.0	2.5	2.5	9.75	9.75	13.5	13.5	......	......	......	......
Front-wheel fork pins, two	13.75	13.75	......	......	......	......	......	......	4.0	4.0	......	......
Rear-wheel fork pins, two	12.5	12.5	......	......	......	......	......	......	3.0	3.0	......	......
Long braces, 8-inch gun, two	52.75	52.75	1.25 3.5	1.25 3.5	4.0	4.0	......	......	......	......	......	......
Short braces 8-inch gun, two	5.2	5.2	3.5	3.5	4.0	4.0	......	......	......	......	......	......
Rear-wheels, top-carriage, two.	......	...	3.25	3.25	......	......	......	......	13.5	13.	......	......
Rear-wheel axles, top-carriage, two.	9.875	9.87	......	......	......	......	......	......	3.0	3.0	......	......

sions of component parts.

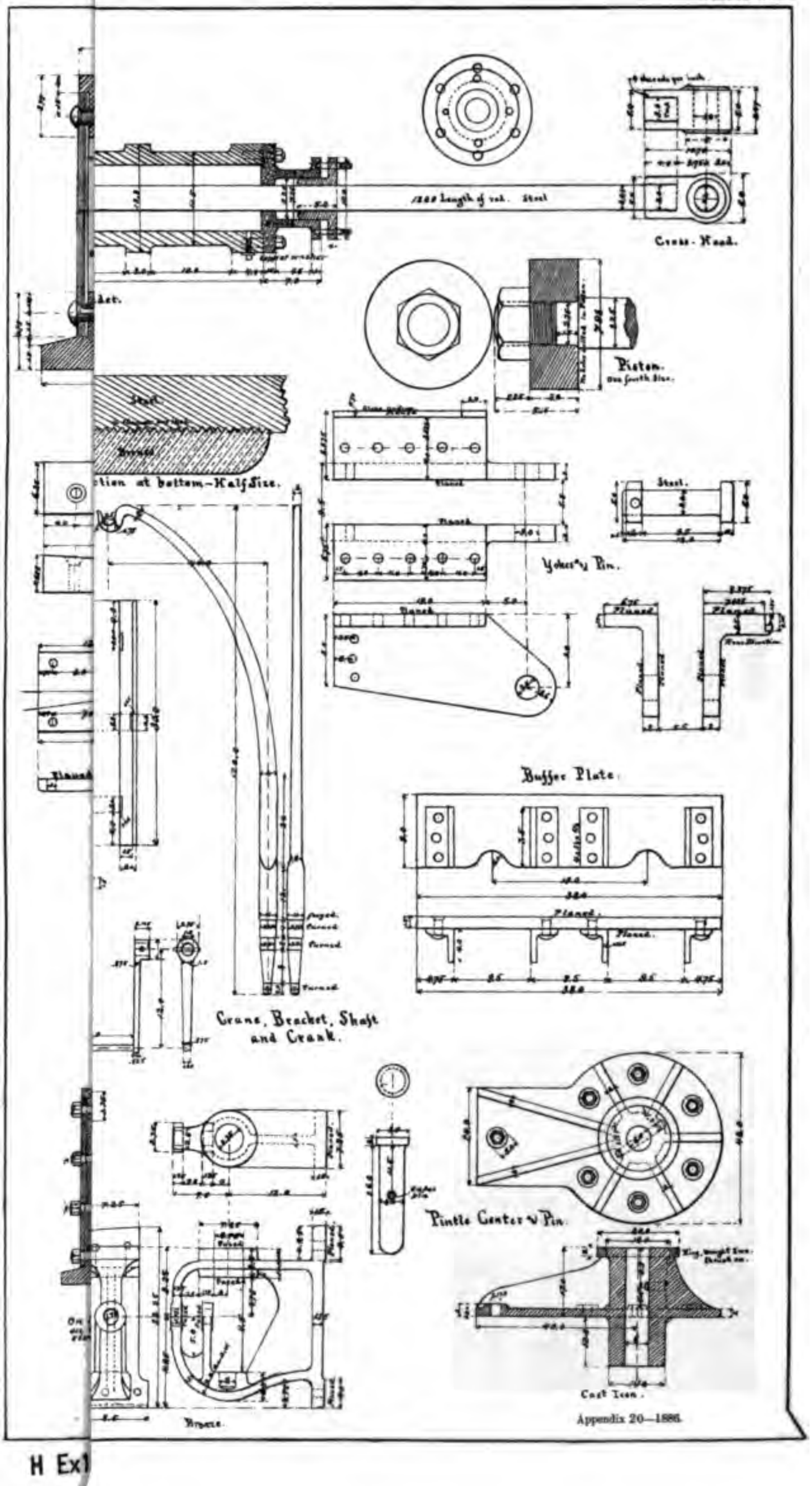
Length of flange.		Thickness of flange.		Width of flange.		Diameter of bore.		Threaded or tapped. Diameter.		Threaded or tapped. Length.		No. of teeth.	Remarks.
Prescribed.	Actual.	Prescribed.	Actual.	Prescribed.	Actual.	Prescribed.	Actual.	Prescribed.	Actual.	Prescribed.	Actual.	Prescribed and actual.	
In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*		
....	....	1.0	0.875	4.0	4.35	....	....	....	....	....	....	....	(Where material is not noted it is wrought-iron.)
....	....	1.0	0.95	4.0	4.6	....	....	....	....	....	....	....	
....	....	....	....	....	....	....	....	....	....	....	....	....	
....	....	....	....	....	....	....	....	....	....	....	....	....	Positions of bolt-holes slightly changed to avoid rivets.
....	....	....	....	....	....	....	....	....	....	....	....	....	
....	....	....	....	....	....	....	....	....	....	....	....	....	
....	....	....	....	....	....	....	....	....	....	....	....	....	
....	....	1.0	1.0	4.25	4.25	....	....	....	....	....	....	....	
....	....	....	....	....	....	6.0	6.0	....	....	....	....	....	Planed for pintle-center and rails.
....	....	....	....	....	....	....	....	....	....	....	....	....	Carries four rubber buffers.
....	....	....	....	....	....	....	....	....	....	....	....	....	Do.
....	....	....	....	....	....	....	....	....	....	....	....	....	Planed 1 inch thick under cheeks.
10.0	10.0	1.0	1.05	13.0 8.0	13.0 8.0	11.5	11.49	....	....	....	....	....	Fitted between collars on cylinders.
								3.0	3.0	4.0	4.0		
....	....	....	....	....	....	....	....	2.75	2.75	1.5	1.5	....	Machinery, steel.
....	....	....	....	....	....	3.2	3.2	3.0	3.0	4.0	4.0	....	Screwed on piston-rods.
....	....	....	....	....	....	....	....	2.75	2.75	1.5	1.5	....	No holes drilled for passage of oil. One piston has two threads slightly defective.
28.	28.	1.5	1.5	9.75	9.75	....	....	3.5	3.5	....	....	....	
....	....	....	....	....	....	....	....	3.5	3.5	8.0	8.0	....	Have hand-spike holes in heads.
3.0 4.0	3.0 4 0	2.75	2.65	....	....	8.0	Mean. 8.005	....	....	....	....	....	Bore was star-gauged; steel.
3.0 4.0	3.0 4 0	2.75	2.65	....	....	8.0	Mean. 7.9995	....	....	....	....	....	Do.
16.5	16.5	1.5	1.5	16.5	16.5	....	....	11.5	11.5	7.0	7.0	....	Grooves for packing; bronze.
....	....	1.5	1.5										
....	....	1.0	1.0	....	....	5.25	5.25	....	....	....	....	....	Form stuffing-boxes; bronze.
....	....	1.0	1.0	....	....	3.25	3.25	....	....	....	....	....	Bronze.
		1.5	1.5	....	....	3.75	3.75						
7.25	7.25	1.0	1.0	....	....	1.75	1.75	....	....	....	....	....	Bored for crane and bevel-gear axle; bronze.
....	....	....	....	....	....	2.0	2.0	....	....	....	....	..	Hub bronze. Clamp: length, 16; depth 3.5.
....	....	....	....	....	....	13.03	13.03	....	....	....	....	....	Forged steel. Collars: Diam. 16.5; width, 1.5.
....	....	....	....	4.0	4.0	11.03	11.03	....	....	....	....	....	Cast steel. Collars: Diam., 16.5; width, 1.5.
19.0	19.0	2.5	2.5	8.375	8.375	3.0	3.0	....	....	....	....	....	Bolted to L-iron for attachment to buffer plate. Flanges notched and beveled to form guides.
19.0	19.0	1.5	1.5	6.75	6.75	3.0	3.0	....	....	....	....	....	Bolted to L-iron for attachment to buffer plate.
....	....	....	....	....	....	....	....	....	....	....	....	....	Head: Length, 2.0. Diam., 5.0; steel.
....	....	....	....	....	....	3.03	3.03	....	....	....	....	....	Six hand-spike holes in each for traversing. Diameter hub, 5.0; thickness, 4.95.
....	....	....	....	....	....	4.03	4.04	....	....	....	....	....	Hub: Diameter, 7; thickness, 4.7.
over all. 13.0	13.0	1.5	1.5	9.75	9.72	3.0	3.0	....	....	....	....	....	Four pieces in all. All shaped askew.
20.0	20.0	1.5	1.5	9.75	9.75	4.0	4.0	....	....	....	....	....	Two pieces in all.
....	....	....	....	....	....	....	....	....	....	....	....	....	Steel. Heads: Diameter { 6.0. 5.5 } Body has feather.
....	....	....	....	....	....	....	....	3.0	3.0	2.0	2.0	...	Steel; heads { Hex. nut. Diameter, 4.25. } Body feathered.
....	....	....	....	....	....	....	....	....	....	....	....	....	Fitted to flange of gun-ring.
....	....	....	....	....	....	....	....	....	....	....	....	....	Fitted to flange of gun-ring.
....	....	....	....	....	....	5.02	5.02	....	....	....	....	....	Hubs: Diameter, 8.0, thickness, 3 5.
....	....	....	....	....	....	....	....	....	....	....	....	....	Steel. Diameter of worm-wheel-arm, 2.5. Diameter of eccentric, 5; eccentricity, 1.0.

Table of principal dimensions of

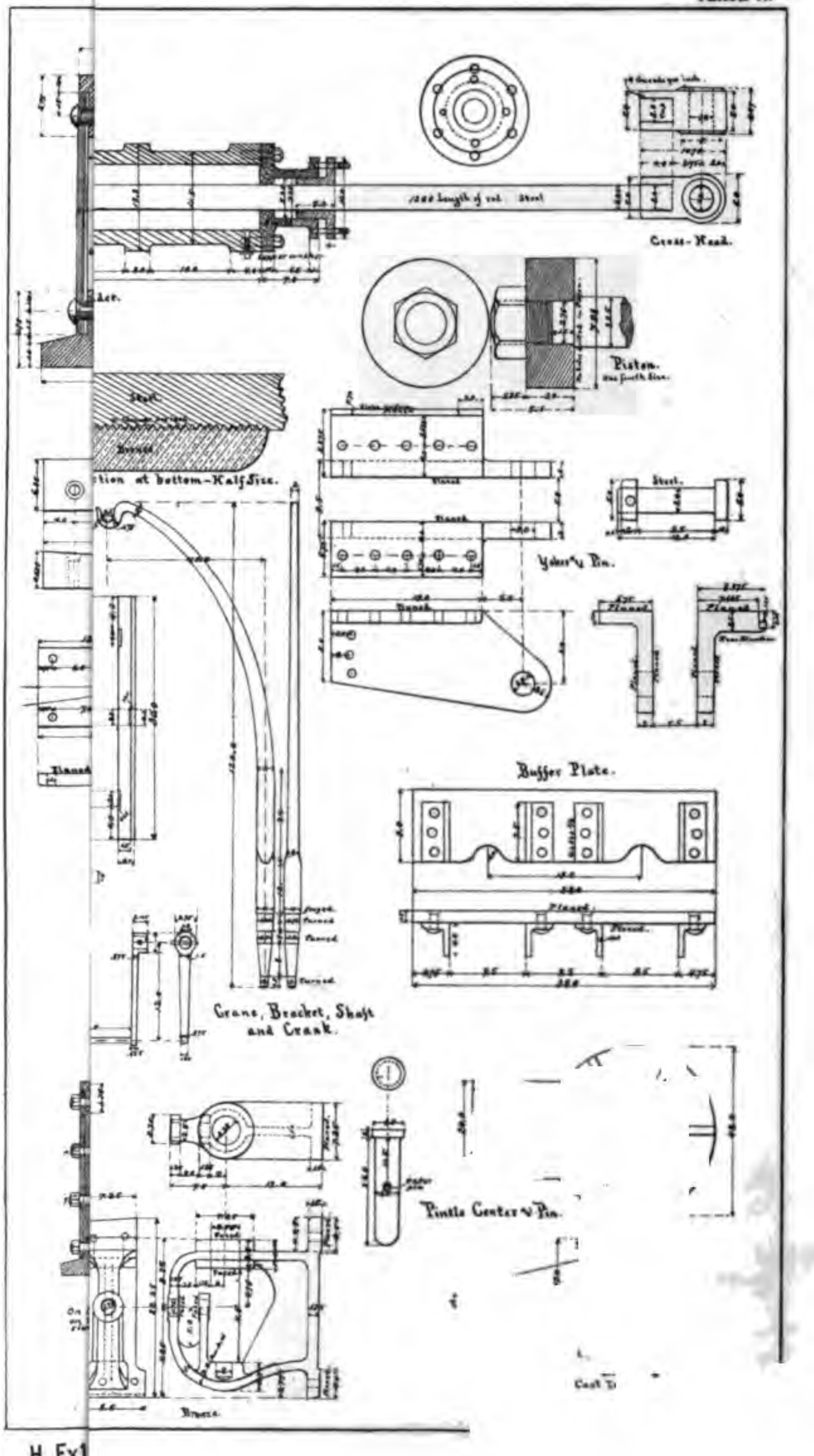
Subject of measurement.	Total length.		Total thickness.		Total width.		Total depth.		Diameter.		Diameter of flange.	
	Prescribed.	Actual.	Prescribed.	Actual.	Prescribed.	Actual.	Prescribed.	Actual.	Prescribed.	Actual.	Prescribed.	Actual.
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
Front wheels, top-carriage, two.	.....	.....	3.25	3.25	.....	....	.....	.....	14.0	14.0	.....	.....
Front-wheel axles, top-carriage, two.	7.5	7.55	.....	...	.....	.....	.....	.....	5.5	5.5	.....	.....
Front-axle bushings, four	.....	.....	1.87	1.80	.....	.....	.....	.....	8.5	8.5	12.0	12.0
Rear-axle bushings, four	.....	.....	1.87	1.87	.....	.....	.....	.....	5.05	5.04	9.0	9.0
Bevel gear, follower	.....	.....	2.3	2.3	.....	.....	.....	.....	9.6	9.6	.....	.....
Bevel gear, pinion	.....	.....	2.375	2.37	.....	.....	.....	.....	4.8	4.8	....	.....
Crane	120	120	4.0	4.0	40	40	.....	.....	.....	.....	.....	..
Worm-wheels, two	.....	.....	2.5	2.25	.....	.....	.....	.....	8.96	8.91	...	.....
Racks, 10-inch gun, two	28.0	28.0	2.0	2.0	6.5	6.5	....	.....	P. D. 127.7	P. D. 127.7	.....	.....
Racks, 8-inch gun, two	33.5	33.5	2.0	2.0	5.0	5.0	.....	..	P. D. 112.3	P. D. 112.3	...	...
Hand-wheel shafts, two	14.55	14.5	.....	...	.....	.....	.....	.....	2.0	2.0	...	....
Hand-wheel shafts, bushings, two.	6.25	6.25	0.5	0.5	.....	.....	.....	.....	3.0	3.0	6.0	6.0
Hand-wheel shafts, pinions, two.	.....	.....	2.0	2.0	.....	.....	.....	.....	P. D. 5.44	P. D. 5.43	....	.....
Intermediate shafts, 10-inch gun.	10.55	10.55	.....	....	.....	.....	.....	.....	2.5	2.5	.....	.....
Intermediate shafts, 8-inch gun.	14.675	14.675	.....	....	.....	.....	.....	.....	2.5	2.5	.....	.....
Intermediate shafts, bushings, two.	6.25	6.25	0.5	0.5	.....	.....	.....	.....	3.5	3.5	6.5	6.5
Intermediate shafts, pinions.	.....	.....	2.0	2.0	.....	.....	.....	.....	P. D. 6.0	P. D. 6.0	....	.....
Intermediate shafts, spur-wheels.	....	....	2.0	2.0	.....	.....	.....	.....	P. D. 13.76	P. D. 13.76	....	.....
Rack-pinion shafts, 8-inch and 10-inch gun.	13.0; 11.0	13.0; 11.0	.....	....	.....	.....	.....	.....	3.0	3.0	....	...
Rack-pinion shafts, bushings	6.1	6.15	0.5	0.5	.....	.....	.....	....	4.0	4.0	7.0	7.0
Rack-pinion shafts, spur-wheels.	.....	.....	2.0	2.0	....	.....	.....	.....	P. D. 18.0	P. D. 18.0	.....	.....
Rack pinions	.....	.....	2.5	2.5	.....	.....	.....	.....	P. D. 7.68	P. D. 7.68	.....	.....
Worms and shafts, two	10.0	10.0	.....	....	.....	.....	.....	....	P. D. 3.25	P. D. 3.25	.....	.....
Hand-wheels, worm shaft, two.	.....	....	1.125	1.2	.....	.....	.....	.....	12.0	12.0	.....	....
Rack trunnions, 10-inch gun, two.	.....	..	1.0	1.0	.....	.....	12.0	13.0	Plate. 39.8	Plate. 39.8	.....	.....
Rack trunnions, 8-inch gun, two.	.....	...	1.0	1.0	.....	....	12.25	12.25	Plate. 31.5	Plate. 31.5	....	....
Studs and rolls, 10-inch gun two.	11.25	11.25	.....	...	....	..	.....	.....	2.0	2.0	....	..
Rolls for 8-inch gun, two	2.7	2.7	.....	...	.....	.....	.....	.....	4.0	4.0	5.75	5.75
Plugs for chassis, two	6.3	6.3	.....	...	.....	.....	.....	.....	5.5	5.5	6.5	6.5
Worm-wheel bearings, upper, two.	6.0	6.0	.....	..	7.0	7.0	.....	.....	3.0	3.0	.....	.....
Worm-wheel bearings, lower, two.	2.75	2.75	.....	....	6.75	6.75	Of bore. 1.5	Of bore. 1.5	2.5	2.5	.....	.....
Pintle center	60	60	.....	...	.....	....	29.0	29.0	14.0	14.0	40	40

component parts—Continued.

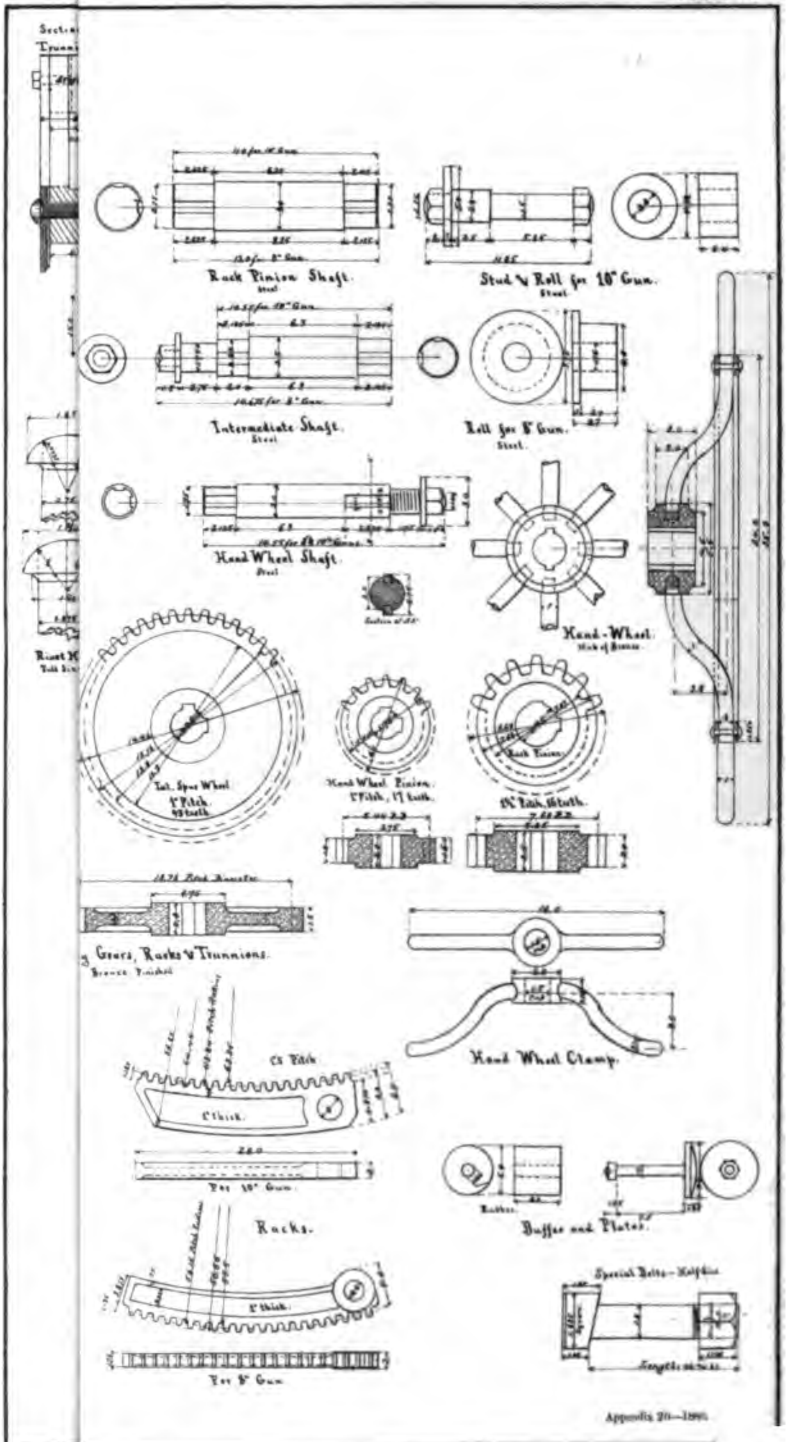
Length of flange.		Thickness of flange.		Width of flange.		Diameter of bore.		Thread ed or tapped. Diameter.		Thread- ed or tapped. Length.		No. of teeth.	Remarks.
Prescribed.	Actual.	Prescribed.	Actual.	Prescribed.	Actual.	Prescribed.	Actual.	Prescribed.	Actual.	Prescribed.	Actual.	Prescribed and actual.	
In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*		
						5.5	5.5						Hubs: Diameter, 9.0; thickness, 3.5.
													Steel. Arms: Diameter, 5.0; length, 2.0.
		1.0	0.93			5.02	5.02						Flanges reduced to cause neat bearing on axles. Eccentricity, 0.35.
		1.0	1.0			3.02	3.03						Bronze.
						3.5	3.5						Pitch, 1.0.
												30	Bronze. Diameter given is pitch diameter.
						1.5	1.75					15	Bronze. Diameter given is pitch diameter. Pitch, 1.0.
						2.5	2.5					28	Bronze. Diameter given is pitch diameter. Pitch, 1.0.
						3.0	3.0					18	Bronze; teeth on concave edge.
						2.5	2.5					21	Bronze; teeth on convex edge.
								1.0	1.0	1.5	1.5		Steel.
		0.75	0.75			2.01	2.02						Bronze.
						1.75	1.75					17	Bronze; pitch, 1.0.
													Steel, two.
													Do.
		0.75	0.75			2.51	2.51						Bronze, two.
						2.25	2.25					15	Bronze, two; pitch, 1.25.
						2.25	2.25					43	Bronze, two; pitch, 1.0.
													Steel, two of each.
		0.75	0.75			3.01	3.01						Bronze, two; and two for 8-inch gun, 8.25 long.
						2.75	2.75					45	Bronze, two; pitch, 1.25.
						2.75	2.75					16	Bronze, two; pitch, 1.5.
								4.0	4.0	4.5	4.5		Steel; shaft, 1.5 diameter; pitch, 1.0.
						1.30	1.27						Bronze; keyed to shaft.
													Bronze; diameter trunnion, 3.0.
													Bronze; diameter trunnion, 2.5.
						2.0	2.0	1.0	1.0	1.25	1.25		Steel, roll; length, 2.4; diamter, 4.32.
		0.7	0.7			1.75	1.75						Steel; on intermediate shaft.
													Bronze; diameter stem, 1.5.
		0.875	0.875	2.0	2.0	1.5	1.5						Bronze.
		0.875	0.875			1.25	1.25						Bronze; cut away for bushing.
60	60	2.0	2.0	24	24	6.0	6.03						Cast-iron, with wrought-iron ring shrunk on.


Cross-Head.
Piston.
One fourth Size.
ction at bottom—Half Size.
Yokes & Pin.
Buffer Plate.
Crane, Bracket, Shaft and Crank.
Pintle Center & Pin.
Cast Iron.
Bronze.

H Ex1


Cross-Head.
Piston.
One fourth Size.
Yokes & Pin.
Buffer Plate.
Crane, Bracket, Shaft and Crank.
Pintle Center & Pin.
Section at bottom-Half Size.
Steel
Bronze
Planed
Forged
Turned
Cast

H Ex1


Rack Pinion Shaft.
Steel.
Stud & Roll for 10" Gun.
Steel.
Intermediate Shaft.
Steel.
Roll for 8" Gun.
Steel.
Hand Wheel Shaft.
Steel.
Hand-Wheel.
Hub of Bronze.
Int. Spur Wheel
1" Pitch
45 teeth.
Hand Wheel Pinion.
1" Pitch, 17 teeth.
Rack Pinion.
1¼" Pitch, 16 teeth.
Rivet H
Gears, Racks & Trunnions.
Hand Wheel Clamp.
Racks.
For 10" Gun.
For 8" Gun.
Rubber.
Buffer and Plates.
Special Bolts—Half Size

H Ex1

APPENDIX 21.

TWELVE-INCH PROJECTILES FOR BREECH-LOADING RIFLE WITH EXPERIMENTAL BANDS.

BY CAPT. ROGERS BIRNIE, JR., ORDNANCE DEPARTMENT.

(1 plate.)

WEST POINT FOUNDRY,
Cold Spring, N. Y., January 5, 1886.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.:

GENERAL: In connection with the inspection report forwarded December 17, 1885, upon the banding of 274 12-inch breech-loading cored shot intended for the 12-inch breech-loading cast-iron rifle completed this year at the South Boston Iron Works, I have the honor to submit a summary account of the construction of those shot and the several experimental bands which have been made at this foundry under instructions from your office during the progress of the proof-firing of the gun to this date at Sandy Hook. The projectiles named above constituted the remainder of the original number (three hundred and nine) completed December 30, 1884, under contract of October 4, 1884, comprising one hundred and three shot of 700, one hundred and five of 750, and one hundred and one of 800 pounds weight, made without bands.

The accompanying drawing shows the form and dimensions of the shot and bands which were supplied for trial in lots as follows:

(1) April 21, 1885, five of 700, three of 750, and two of 800 pounds weight; in all, ten shot with Hotchkiss bands. (See fig. 5.)

(2) May 9, 1885, three of 700, three of 750, and four of 800 pounds weight; in all, ten shot with single bands, modified A, fig. 3, made of strips of rolled plate copper not annealed.

(3) May 9, 1885, similar to lot 2 above, ten shot with double bands, B, fig. 4, also made of strips of rolled plate copper not annealed.

The three preceding lots were ordered for trial in common by way of first experiment to determine the proper nature and dimensions of band as well as its proper position upon the projectile, *i. e.*, its distance from the base.

(4) August 13, 1885, five of 800 pounds weight, with single bands, C, fig. 1, cast from an alloy of 95 parts copper and 5 parts spelter. These bands, which were made of softer material than the preceding, are also seen to be of less width and placed further forward on the projectile. They gave satisfactory results and led to the following:

(5) Contract of November 11, 1885 (comprising the remainder of the shot on hand), ninety-two of 700, ninety-six of 750, and eighty-six of 800 pounds weight; in all, two hundred and seventy-four shot, of which

one-half of each kind was furnished with cast-copper bands of the alloy given above, and one-half with bands made of strips of rolled plate copper, *annealed* immediately preceding their assemblage. All of these bands were given the dimensions and position of C, fig. 1, except ten of the 800-pound projectiles, upon which the bands were placed 1.0 inch farther forward. (See fig. 6.) This last modification having been determined consequent upon the success of similar trials with 8-inch breech-loading projectiles.

THE BODY OF PROJECTILES (CAST IRON).

Design.—Fig. 1 shows the form and dimensions of the 700-pound shot, with changes of dimensions noted for the two remaining weights. The radical change in the form of body from previous types, especially muzzle-loading projectiles, consists in the reduction of the cylindrical portion of body over the whole rear portion, leaving a raised band of 3 inches width at the base of the head, which centers the forward portion of the shot within practicable limits for loading.* This front band is joined to the rear of the body by a conical surface of slight slope. The clearance for loading is 0.03 of an inch over the band and 0.07 over the rear cylindrical portion of body.† The curve of the head is made up of the arcs of two circles, which have a common tangent line at a point 4.5 inches from the base of the head. The radius of the arc forming the base is 1.5 calibers (18.0 inches), and this arc is tangent to the body at the base of the head. The radius of the arc outlining the front of the head is two calibers (24.0 inches).

In arranging the dimensions of these projectiles for manufacture the primary conditions laid down were: Taking the heaviest to govern, the weight of shot complete should be 800 pounds, the total length 3 calibers; the core contains not less than 200 cubic inches of empty space, and the curvature of the head made with a radius of 2 calibers, if practicable, or, at most, not less than 1.5 calibers.‡ The 750 and 700 pound projectiles would then be determined by simply shortening the cylindrical portion of body at rear. It was found that with a full head of 2 calibers radius, that is, with a head tangent to the body at base, the weight of 800 pounds could not be contained within the total length of 3 calibers. The head of two curves was then adopted to obtain the proper weight within the given length, and at the same time make the head tangent to the body at the base of the head. At the same time, also, the length of head in comparison with that of body was reduced to suitable proportions,§ and the curve of 2 calibers radius retained for the main portion

* Since the issue of the type drawing from the Ordnance Office (May, 1884) for this projectile, the same profile of body has been applied in making the 580, 585, and 610 pound shell for 12-inch muzzle-loading rifled mortar, and also for 8 and 10 inch breech-loading projectiles.

† The question of making these clearances 0.02 and 0.05 of an inch, respectively, was negatived in consequence of some difficulty found in loading 12-inch muzzle-loading mortar projectiles, for which the clearances were 0.03 and 0.07 of an inch.

‡ Taking the space occupied by powder as 0.035 of a pound per cubic inch, this core would contain a charge of 7 pounds. It is stated that in the present Krupp projectiles the radius of the curve of head is 2 calibers, in the Italian service 2.5 calibers, and in the French service 3 calibers. In ordnance notes No. 174, however, is shown an Italian projectile of 2,200 pounds weight, in which the curve of the head is made up of the arcs of several circles.

§ The full head of 2 calibers radius would have made the length of head 15.86 inches instead of 14.57 as used. That defect could have been remedied by lengthening the body and making the head something less than a full curve, thus leaving a somewhat abrupt change of outline at the base of head. It is questionable how far such a change of outline would affect the flight of the shot; however, it must probably always be done in cases where a single curve of 2 calibers or greater radius forms the head of a shot not more than 3 calibers total length.

of the head towards the point. (See fig. 1.) This form of head appears to embody all the advantage of the sharpness of point given by a curve of 2 calibers radius, and to obviate the abrupt change of outline before mentioned.

To compute the cubical contents and fix the dimensions of the 800-pound shot, a density of 7.20 was assumed for the cast iron. The band was computed to weigh 5.4 pounds, and the screw plug 3.0 pounds, leaving 791.6 pounds of cast iron. The cubical contents corresponding to this weight for a density of 7.20 is found to be 3.046 cubic inches.* Adding to this the 200 cubic inches of core space, the outline of shot to contain 3,246 cubic inches within a length of 3 calibers was determined by trial computations. For the two remaining weights requiring a successive reduction of 50 pounds, the cylindrical portion of body was reduced in length 1.72 inches and 3.44 inches, respectively. Determined as follows: Fifty pounds at density 7.20, corresponds to 192.3 cubic inches, and a solid cylinder 11.93 inches in diameter should be 1.72 inches long to contain 192.3 cubic inches.

Manufacture.—A sample shot of each size was cast first to test the weight. In each the weight of cast-iron fell between 10 and 1¼ pounds short, but the actual densities were comparatively low, 7.19 and 7.2357, for the required tenacity (not less than 28,000 pounds per square inch), and it was deemed sufficient to add 0.125 of an inch to the base of each, so as to increase the weights about 3.5 pounds and bring them within the minimum allowed variation of minus 1 per cent. of the standard weights. The drawing, Fig. 1, gives the dimensions used in the manufacture, the lengths of body, distances from point of core to point of projectile, and the total lengths being each increased 0.125 of an inch over the original design. As a final result we find the following:

Projectile.	Weight of cast iron.		Average loss in weight.	Density of cast iron.	
	Estimated.	Actual (average).		Estimated.	Actual (average).
	Pounds.	*Pounds.*	*Pounds.*		
700-pound	691.6	685.4	6.2	7.20	7.268
750-pound	741.6	734.0	7.6	7.20	7.2353
800 pound	791.6	785.0	6.6	7.20	7.2810

Showing an average loss of weight from the prescribed (estimated) which may be put at 7 pounds for each, and a note to this effect has been placed on the drawing to govern future manufacture. The cause of this loss of weight appears (assuming the computation of cubical contents to have been correct) to lie in the density assumed for original computation, and we find that if the density for computation of weight had been assumed at 7.10 (nearly) *instead of* 7.20, the design of shot would have included the cubical contents needed to produce the prescribed weights; in other words, the cubical contents of shot (core included) should have been 3,287 cubic inches instead of 3,246, an increase of 41, corresponding to the additional length 0.125+0.24=0.365 of an inch, found necessary from the outcome of manufacture.

Observing that the average actual density for the three lots was 7.26, and that we should have used a density of 7.10 for the computation, there

*Computed by Table VIII. Ordnance Office, August 20, 1884.

is shown *a loss of about 2 per cent. of density or of weight which this manufacture shows should be allowed in computing the dimensions of projectiles of the weight and type under consideration.* We may account for a very small part of this loss by the draw or strain of the core which took place about its point, but the principal cause must lie in the lack of uniformity of density in the mass of iron. The specimens for actual density recorded were taken from the thinnest part of the wall of shot opposite the core. The density at this place is considerably greater than in the center of the thick mass which forms the head of the shot; the mass there cools last in the casting, and the iron is drawn towards the center, as shown outwardly in the draw at the point of core.

These shot were cast point down and fed with hot iron at two risers from the base. If the shot were cast point up and the hot iron fed into the head, that portion might be expected to have a more uniform density, and there would not be so great a loss of weight as shown above. The disadvantage found in casting shot point up is that the point does not possess the strength obtained by the reverse method, and is apt to be unsound even, although this may be remedied by having a sufficient riser or sinking head at the point. In the present work an attempt was made with one lot (15) to cast point up. The whole cast was lost by the stripping of the cores from their stems, which were made for the reverse method of casting. These stems were tapered towards the point, and when set point up the cores were stripped upwards, this action being probably assisted by the burning of the wrapping around the stem of the core below, which in this position was exposed to a greater heat than in the reverse method where it is near the top of the casting. A core-stem having studs or other projections around which to build the core would be necessary in casting these shot point up. And, referring to what has been said before, if these shot should hereafter be cast in this way, the shot would probably be heavier, yet would still not exceed the maximum allowed variation of plus 1½ per cent. of the weight, including the addition to the length noted on the drawing.

RECORD OF CASTINGS.

The following table gives a record of the lots of shot cast, the mixtures of iron (in percentages) in the air-furnace from which the castings were made direct, and the average weights of shot in the rough and finished state:

Record of castings and tests of 700, 750, and 800 pound 12-inch cored shot.

Date.	Number cast.			Number accepted.	Charge of iron in percentages.									Physical qualities.				Average weights.	
														From proof-bar.		From specimen shot.			
	700-pound.	750-pound.	800-pound.		Gere No. 2.	Gere No. 3.	Hudson No. 2 (extra).	Poughkeepsie No. 1.	Air furnace scrap.	Old welding-pots.	Old shot and shell.	Gun-scrap.	Cupola scrap.	Tenacity.	Specific gravity.	Tenacity.	Specific gravity.	Rough.	Finished (without plug).
1884.																			
Oct. 25	1	....	....	1	3.2	17.4	....	....	10.3	47.7	15.4	5.8	..	27.689	7.3150	28.502	7.1910	702.0	....
																		758.0	731.0
Nov. 1	....	1	1	2	30.9	..	....	....	12.9	38.7	..	17.3	...	25.943	7.3043	30.467	7.2357	809.0	780.0
5	8	....	....	3	23.5	....		..	22.3	33.1	..	20.9	....	24.114	7.3620	28.394	7.3273	708.8	.
7	15	....	..	8	30.0	..	....	..	7.5	37.5	7.5	17.5	...	27.464	7.3466	31.184	7.3029	708.2	688.7
8	15	....	.	13	16.6	16.6	..	..	7.0	41.6	..	18.0	....	29.352	7.3082	30.467	7.2488	708.4	687.2
10	15	...	...	15	17.1	17.1	....		20.0	20.3	...	16.4	....	25.987	7.3968	27.680	7.3303	713.2	693.7
11	15	....	..	13	17.6	17.6	....	4.4	5.8	33.8	...	20.5	....	30.812	7.2781	30.237	7.2208	706.3	685.2
12	15	....	....	13	17.6	17.6	....	4.4	..	37.5	..	22.8	..	28.627	7.2858	31.050	7.2364	709.2	687.5
13	15	....	....	12	..	22.5		....	18.8	32.3	.	21.0	5.2	29.670	7.4020	29.522	7.3525	714.1	695.2
15	14	..	..	10	4.4	..	20.8	...	22.2	31.9		20.8	..	33.995	7.2944	28.966	7.2231	711.4	687.5
17	...	15	...	8	24.5	6.6	6.6	....	..	28.5	17.9	15.9	....	23.332	7.3143	30.300	7.2680	762.7	[illegible]
18	....	15	...	14	28.5	..	10.0	..	21.4	15.7	22.8	1.4	...	26.169	7.3302	29.833	7.3091	765.0	742.0
21	....	13	....	13	37.7	..	6.3	...	..	27.6	23.3	5.0	....	27.126	7.2689	28.670	7.2012	759.2	735.4
24	....	15	....	15	12.6	..	25.7	..	...	...	61.6	....	..	29.779	7.3125	28.175	7.2509	764.0	739.0
25	....	11	....	10	.	..	28.5	...	33.1	18.5	19.8	....	...	30.264	7.3278	28.854	7.2100	761.7	734.7
Dec. 1	....	15	....	15	16.9	..	17.5	...	6.7	25.0	16.9	16.9	...	30.109	7.2636	29.041	7.2328	763.4	736.3
2	....	15	....	13	10.0	..	16.6	..	20.0	23.3	13.3	16.6	....	29.621	7.2967	28.274	7.2269	763.2	738.7
3	15	....	...	15	21.4	..		..	21.4	39.3	....	17.8	...	29.621	7.2707	29.172	7.2115	710.3	685.8
4	....	...	15	14	...	23.6	..	..	14.6	12.5	49.3	..	..	24.691	7.3576	30.722	7.3148	813.3	789.7
6	...	...	15	14	17.8	...	20.5	...	31.5	4.8	6.8	....	18.5	20.958	7.2913	29.123	7.2418	814.3	787.1
8	....	...	15	14	20.0	..	6.6	...	31.3	...	26.0	16.0	....	26.883	7.3920	30.237	7.3315	816.0	792.8
12	...	16	....	16	22.3	...	13.1	..	26.3	22.3	...	15.8	..	30.210	7.2844	28.285	7.2236	761.6	736.0
13	....	....	14	14		23.0	13.1	..	26.3	13.8	..	....	23.7	22.515	7.3289	27.825	7.2977	806.0	787.0
18	....	....	15	14	16.4	...	...	...	45.4	13.1	...	18.5	6.5	30.120	7.3498	29.472	7.2722	815.7	790.2
20	....	...	15	15	16.6	....	16.6	...	..	13.3	21.3	18.6	13.3	28.001	7.3219	30.763	7.2398	814.3	785.8
22	....	....	16	15	24.8		14.2	....	30.8	..	6.5	13.0	10.6	31.363	7.3479	31.947	7.2727	816.0	786.7

The record gives a variety of suitable mixtures for obtaining a tenacity of not less than 28,000 pounds per square inch; and, taken in connection with the results obtained from castings with mixtures containing no gun-metal or old shot from air-furnace castings, it shows the marked advantage of these ingredients.

MANUFACTURE OF THE BANDS.

Hotchkiss band (Fig. 5).—Cast in the form of a ring 2.65 inches long, 11.62 inches interior and 12.35 inches exterior diameter, from an alloy of 95 parts copper and 5 parts zinc or spelter. The shrinkage on the diameter of the casting in cooling is about 0.18 of an inch. Finished first on interior to an easy driving fit over the bands; faced at one or both ends if necessary to true them to 2.48 inches length; placed on shot and ends hammered down into grooves; finally finished over exterior when in place. The weight of the cast band in the rough is 11.6 pounds and its finished weight is 6 pounds. The owners of the patent exact a royalty of 2 cents per pound of finished weight of projectiles on which these bands are used.

Rolled and annealed copper bands.—The manufacture comprised all made like "Modified A," fig. 3, and B, fig. 4, with one-half (137) of all all made like C, figs. 1 and 6. (1) Cut from plates of rolled copper seven-sixteenths of an inch thick in strips 39.5 inches long, using either a

planing-machine or a saw, and cutting to neat width of under side of band, with sides beveled to fit the seat of band in shot. (2) One end of band beveled across width to slope of 45°. (3) Bent or "humped" along middle line to reduce the width to that of mouth of groove in shot, using a hydraulic press with triangular matrix and die. (4) Annealed by heating to a low red heat and plunging into water. (5) Laid in groove of shot and hammered down with sledges to fill the groove. The hammering is begun at the prepared end of strip and completed progressively around the shot; when the circle is nearly completed the unfinished end of strip is cut across diagonally with a hand-saw to make a neat meeting with the end already in place. (6) The shot is mounted in a lathe and the exterior of the band finished in place.

The bands A and B were not annealed, and the toughness shown by the metal in finishing led to the modification of A, shown in fig. 3, viz, two grooves encircling the band.

A saw was used, with great economy in material and labor, for cutting out the strips for the greater portion of these bands. The saw was 5 inches in diameter. It was mounted on the standards of a planing-machine, and geared to run at first about 300 revolutions per minute. This motion proved too slow, and was afterwards changed to nearly 700 per minute. This speed was retained, but the saw heated rapidly, and it is considered that 500 revolutions per minute would be a proper speed. The sheets of copper were cut across on a planing-machine to sections of proper lengths for the strips, and also beveled along one edge to proper slope for side of band. The sections were then mounted on a sloping frame-work (wood) attached to the slide-plate of the planing-machine on which the saw was mounted. In this position the slope of the copper plate caused the saw, which was set vertically, to give a proper bevel to the edge ol the strip, and the plate was loosened and turned upside down after each cut. The feed was required to be so slow that in the case named it was done by hand; however, with the higher rate of speed one cut (39.5 inches) could be run through in about seven minutes. A reservoir of oil connected with a rubber tube was used to lubricate at the cutting place of the saw. The slide passed the plate under the shaft of the saw, which revolved to cut from below upwards.

The finished weights of these bands is: For modified A, 7 pounds; for B (aggregate of 2), 6.25 pounds; and C, 5 pounds. The loss of raw material may be taken at about 40 per cent. of the weight of the saw used in cutting the strips, and 45 per cent. if a planing-machine is used.

Cast copper bands.—The manufacture comprised in all 142 bands made of the dimensions of C, figs. 1 and 6. The alloy for the casting is 95 parts of copper and 5 parts of zinc. The bands are cast in two parts, each comprising one-half the circle. The ends of these half-bands are cast with a bevel of 45° diagonally across the width; the width of the casting is made equal to that of the mouth of the groove in the shot (1.35 inches), and the form of the cross-section is bowed, having parallel sides, but a concave about 0.25 of an inch deep on the interior, and a corresponding convexity on the exterior. The radius of the interior circumference is made 6.0 inches, and the normal thickness of the casting 0.50 of an inch. The rough weight of these bands is 8 pounds and the finished weight 5 pounds. Before assembling, the parts of the band are dressed with a file, including the two diagonal ends of one-half and one end of the other. The assemblage is made in the same way as the preceding; after the first half is set in the groove the second is begun

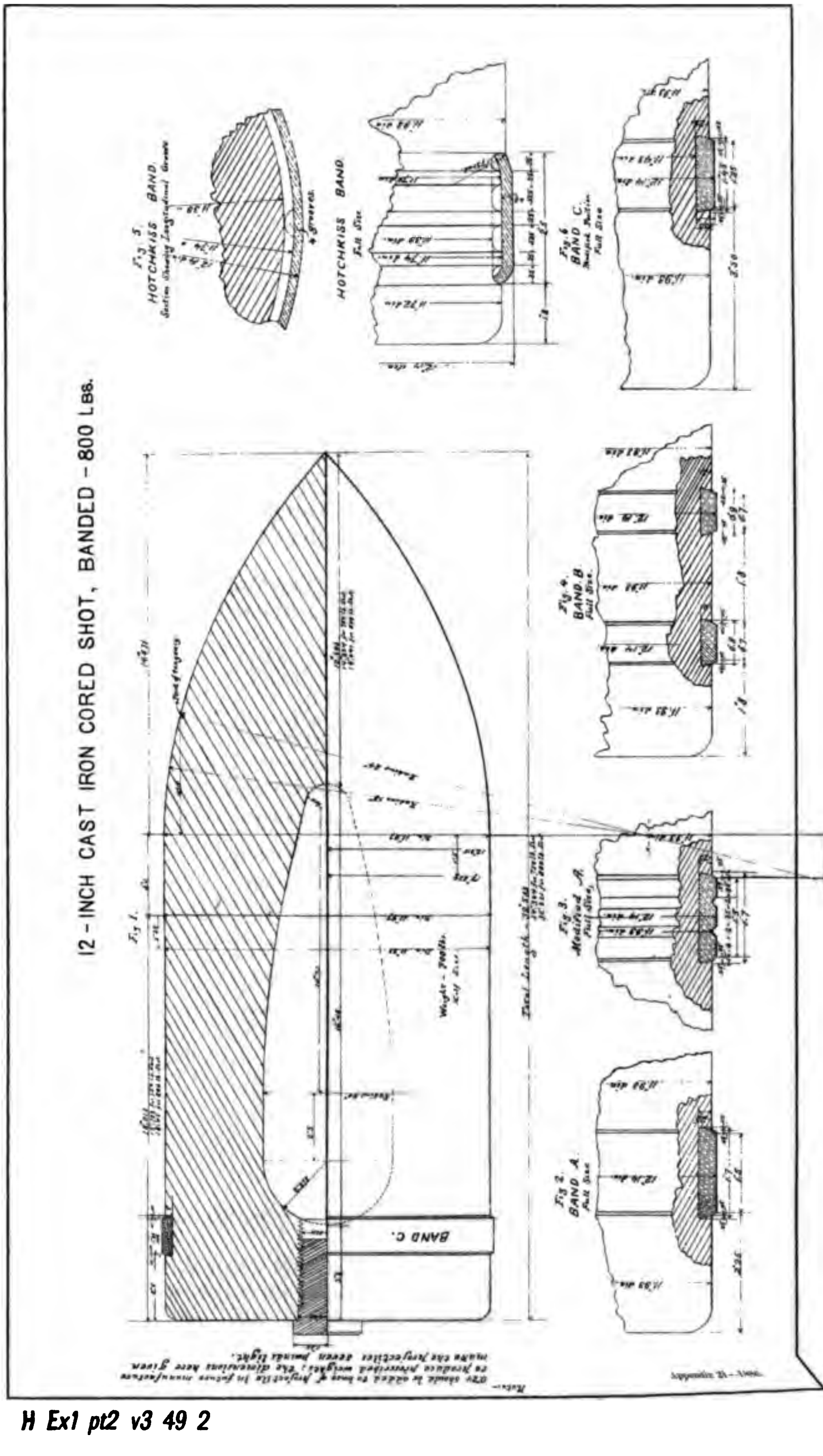
by placing the dressed end in juxtaposition with one end of the assembled piece, and finally the surplus end of the second half is cut off as may be found necessary. The bands are then finished in place.

In all cases, before placing the bands on the shot, a series of cuts, four on each side, were made with a hand-chisel (diamond-point, so called), in the bottom of the groove near the side, to serve as notches to be filled with the metal of the band and prevent the possible turning of the band in firing.

Very respectfully,

ROGERS BIRNIE, JR.,
Lieutenant of Ordnance.

PLATE I.


12-INCH CAST IRON CORED SHOT, BANDED - 800 LBS.
Fig. 1.
BAND C.
Fig. 5.
HOTCHKISS BAND.
HOTCHKISS BAND.
Fig. 6
BAND C.
Fig. 4.
BAND B.
Full Size.
Fig. 3.
Modified A.
Full Size.
Fig. 2.
BAND A.
Full Size.

APPENDIX 22.

ANNUAL REPORT OF CAPTAIN D. A. LYLE, INSPECTOR OF ORDNANCE AT SOUTH BOSTON IRON WORKS, BOSTON, MASSACHUSETTS, FOR THE YEAR ENDING JUNE 30, 1886.

(3 plates.)

THE CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.:

SIR: I have the honor to submit the following report upon the operations undertaken for the Ordnance Department, United States Army, by the South Boston Iron Works during the fiscal year ending June 30, 1886.

During this period the fabrications given in the subjoined list have been undertaken or have been in progress:

List of fabrications.

Order or contract for fortification.	Date of order or contract.	Fabrication.
Unfinished at beginning of fiscal year..	Sept. 24, 1883	(1) One 12-inch B. L. R., hooped and tubed with steel.
	Sept. 24, 1883	(2) One 12-inch B. L. R., steel tube wire-wrapped.
	June 30, 1884	(3) Finishing, assembling, &c., 12-inch B. L. R., hooped and tubed with steel.
	June 30, 1884	(4) Finishing, assembling, &c., 12-inch B. L. R., steel tube wire-wrapped.
Received during fiscal year ending June 30, 1886.	July 6, 1885	(5) Test specimens from hoop A_x (experimental cylinder 12-inch M. L. R. mortar).
	Aug. 17, 1885	(6) Test specimens from second casting for 12-inch B. L. R., steel tube wire-wrapped.
	May 15, 1886	(7) Cast-iron body for 12-inch B. L. rifled mortar.
	May 17, 1886	(8) 300 cast copper bands for 12-inch cored shot.
	May 24, 1886	(9) Test specimens from initial tension ring from fourth casting for 12-inch B. L. R., steel tube wire-wrapped.
	June 22, 1886	(10) 300 10-inch cast-iron cored shot.
	June 22, 1886	(11) 300 shell for 12-inch B. L. rifled mortar.
	June 28, 1886	(12) 300 cast-iron solid shot for 11-inch M. L. rifle.
		(13) 3,000 8-inch cored shot.
		(14) 3,000 8-inch shell.

Of the above list the following numbers have been completed, and disposed of as follows:

No. 5. Test specimens from Hoop A_x (Experimental Cylinder for 12-inch M. L. R. Mortar) were taken out and sent to Watertown Arsenal by express on July 17, 1885. Six tangential extension specimens: 2 outside, 2 middle, and 2 inside.

No. 6. Test specimens from second casting for 12-inch B. L. rifle steel tube, wire wrapped. These tests were included in my last annual report. (See Report of Chief of Ordnance, 1885, p. 347 *et seq.*)

No. 9. Test specimens from initial tension ring of fourth casting for 12-inch B. L. rifle steel tubes, wire wrapped, were sent to Watertown Arsenal June 5, and June 14, 1886. (For results, see below, under 12-inch B. L. R., steel tubed, wire wrapped.)

The other numbers on the list remain unfinished. For Nos. 1, 2, and 3 the contracts have expired. The contract for No. 4 expires October 28, 1886. Congress extended the appropriations available for the fiscal year ending June 30, 1886, to July 31, 1886, and Nos. 1, 2, and 3 were dropped from my progress report after that date, owing to the failure of Congress to pass the necessary appropriation bill to carry on the work. No. 4 will be dropped from my progress report on October 28, 1886, for the same reason.

I.—Twelve-inch Hooped and Tubed B. L. R..

The Whitworth steel tube has been inserted in this gun and the two rows of steel hoops have been shrunk upon the exterior. By the end of July, 1886, the cast-iron portion of the bore was finished, the exterior over the hoops finished, and the breech of the gun faced. Since the expiration of the contracts (of which the South Boston Iron Works was duly notified) the company has continued work on this gun at their own risk.

The condition of this gun at the present time is as follows:

(1) Exterior over hoops and at breech finished.
(2) Chase unfinished.
(3) Muzzle cylinder left for bearing to be turned down and cut off.
(4) Chamber to be finished-bored.
(5) Chamber throat to be countersunk.
(6) Bore to be rifled.
(7) Breech mechanism to be fitted and assembled.

The hooping of this gun was done during my absence under orders. The construction report of the gun is being prepared by Lieut. H. D. Borup, Ordnance Department, U. S. A., who has direct charge of the work.

II.—Twelve-inch Tubed B. L. R.

(1) *Condition of gun.*

The cast-iron body (made from the fourth casting) is in the lathe. On July 1 the sand tool had entered 275 inches, and the following reamers had been inserted to a distance of 272 inches from the breech, viz: 11, 11.25, 11.50, and 11.75 inches. The exteriors of the gun and of the tube were being turned. On July 31 the gun was being bored to 11.9 inches and the steel tube to 11.87 inches.

At the present time the tube is bored up to 11.92 inches, and is rough-turned on the exterior. The gun-body is rough-turned on the exterior, except between the trunnions. The interior is counterbored for the tube to a diameter of 16.5 inches.

(2) *The steel tube.*

On account of the difficulty experienced in obtaining suitable wire for wrapping this tube, the Chief of Ordnance, United States Army, decided,

April 28, 1886, to dispense with it, and line the gun with the steel tube alone, inserted under a slight shrinkage. The change of plan diminished the labor to be performed by the company.

(3) *Breech mechanism.*

The bushing and several parts of the breech mechanism are as reported in last Annual Report.

(4) *Third casting (12-inch tubed rifle).*

The third casting for 12-inch tubed B. L. rifle was made October 16, 1886. The details regarding furnace charges, melting, casting, and the cooling table are appended, marked Table I.

The first and second castings for the body of this gun were lost. They were reported upon last year (see pp. 333 *et seq.*, Report Chief of Ordnance, 1885). The second casting was made December 23, 1884, and by May 23, 1885, the flask, pit, and furnaces were ready to make the third casting. On July 29, 1885, agreeably to the personal request of the president of the South Boston Iron Works, the Chief of Ordnance granted authority to cast this gun breech up. The company claimed that by casting breech up they would apprehend no further trouble as far as the casting was concerned.

The company then removed the sand from the flask, and remolded the gun breech up. This mold was ready by September 5, 1885. The pig-iron first procured was on hand by May 9, 1885. From this date until August 22, 1885, the time was spent by the company in trying to get a satisfactory mixture of iron.

The company then desired to use a mixture said to be Austrian pig-iron, but the Department declined to allow a change from the standard mixture adopted for the trial cylinder to a new and untried metal of foreign production.

This departure of the company from the standard iron caused a further delay until October 16, 1885, when the third casting was made from iron reported to be Richmond pig. This casting ruptured longitudinally from the top of the riser nearly to the trunnions and transversely about half round. By November the casting was removed from the pit, and was then transferred to the lathe to be cut up.

By January 9, 1886, the lower section of the core-arbor was removed and repairing it was begun.

About March 1 Mr. Hunt stated that he had Richmond iron ready for a fourth casting. The flask, pit, and furnaces were ready on April 3, and the fourth attempt to cast the gun was made April 5, 1886.

Loss of third casting.

The circumstances of the loss of this casting, which was made during the writer's absence on leave, are given in the following extracts from the reports of Lieut. Henry Dana Borup, Ordnance Department, U. S. A., Assistant Inspector of Ordnance at this foundry.

Under date of October 16, 1885, Lieutenant Borup reports as follows:

I have the honor to report that a third attempt was made to-day to cast the body for the 12-inch wire-wrapped tubed rifle. The furnaces were tapped at 12.44 p. m., everything proceeding favorably until about 1.12 o'clock, when the normal state ceased. At this time the metal was within about 7 feet of the top of the mold. A great development of gas occurred, causing the metal to boil violently. The flame from the surface rose to a height of about 20 feet.

The water in the arbor rapidly rose in temperature, it being mixed with steam as it issued.

The flames finally ceased. At 12.45 p. m. the temperature of the water entering was 58°. For the first eight or ten minutes there was but little change. At 1 p. m. it was 70°, and from this point it increased regularly till 1.11, when it was 90°. At 1.45 the temperature was 202°. In the interval it could not be taken, as it was issuing in a jet of steam. The rate was changed at the time of the accident from 40 to 50 gallons per minute. The furnaces which had been stopped were again tapped and the mold filled.

At 2.02 p. m. the temperature of water was 202°; at 2.45 p. m. the temperature of water was 172°; at 3 p. m. the temperature of water was 169.

* * * * * * *

The cause of the trouble is at present only a matter of conjecture. The high temperature of the issuing water showed that the coating on the arbor was defective at some point, allowing the metal to fill up the flutes. The proper evolution of gas was stopped, and that in connection with the fact that the arbor had been made up for a month and had probably absorbed moisture, which was set free, caused the boiling and accompanying flame. * * *

Again under date of October 26, 1885, Lieutenant Borup reports as follows:

I have the honor to report that the casting made for the tubed 12-inch rifle on the 16th instant is a failure. Water was shut off on 22d at 4 p.m., having circulated for 147½ hours, during which time the temperature had varied from that of steam to 58°, the same as that of the hydrant water.

The stripping of the flask commenced as soon as practicable. At 5.15 p. m. Saturday, the 24th instant, three sections, aggregating 121¼ inches in length, had been removed, revealing a crack in the piece extending from the upper face of the riser longitudinally downwards as far as the casting was exposed. How much farther it continues cannot be told until the entire flask is stripped.

* * * * * * *

On the 19th instant, about 11.15 a. m. Mr. Arthur Hunt and several of the workmen heard a dull report in the pit, which they supposed was caused by another spider-leg snapping off, but which was undoubtedly the gun itself.

The cause of this failure may be due to the core-arbor coating flaking off on one side and the consequent rapid cooling of the gun in contact with this portion, causing the metal to set and stresses to be thrown on the remaining part, which its strength was not sufficient to withstand.

The cracked casting was transferred to the lathe and eight sections were cut from the breech end, as shown in the accompanying Plate I. The sections are lettered from A to H, in the order of their removal from the breech.

In cutting of the section (A) at 4½ feet from the breech the tool had cut in circumferentially about 3 inches when the metal cracked circumferentially with a loud and startling report, and at the same time a new longitudinal crack opened from this section down toward the trunnions. This was on the opposite side from the first crack and extended toward the trunnions 3.6 inches, and then divided into three branches.

Notwithstanding the wrought-iron bands bolted around the circumference of the casting, the first (original). A crack was open at the breech end of B $1\frac{6}{16}$ inches, and the second (new) crack had an opening of ⅝ inch at the same end, and both extended through the walls of the gun to the core arbor.

The metal around the core-arbor was chilled and presented an appearance similar to that of the Butler chilled shot. The core-arbor was broken off in wedging off the first or breech section, and presented a highly crystalline fracture with coarse crystals, appearing very much like argentiferous galena. The transverse fracture was convex toward the muzzle (lower end), as in the case of the second casting heretofore reported upon.

The fracture showed blow-holes, especially on one side, that were clean, thus showing that they were not due to impurities, but to the imprisoned gases that endeavored to escape up through the melted metal.

The following table gives some data noted during the cutting up of the gun:

Section.	Depth of cut.	Depth of chill at core-arbor.	Thickness of core-arbor—		Size of largest cavity.			Remarks.
			At 0°.	At 180°.	Length.	Width.	Depth.	
	Inches.		*Inches.*	*Inches.*	*Inches.*	*Inch.*	*Inches.*	
A	*3							
B	9	2⅛ to 2⅜ inches ..	0.425	0.9	......	......	......	
C	15	2 inches	....	....	2¼	1	1 1/16	Distance of cavity from exterior, 18 inches.
D	15¼	2 inches	0.875	1.2	1	15/16	3	Cavity 1½ inches deep on one side of cut, and 1⅜" on the other side.
E	15¼	2 inches	....	....	......	......	......	Original crack as large as before; second crack very faint.
F	16	2 inches†	1.2	....	......	......	......	No flutes left on arbor; no evidence of second crack.
G	16	Deeper than F‡.	1.4	....	......	......	......	No flutes. A large section extending from rear of 8th cut (H) to front of 7th (G) split off. It is the end of the original crack.
H	*15	No chill	1.4 1.1	1.3 1.55	......	......	§1.1	Thickness measured over grooves. Thickness measured over flutes.

*About.
†The depth of chill was 2 inches near the crack, and 1 inch in depth at 90° from it.
‡The depth of chill in section G averaged deeper than in F, being from 1½ to 2 inches.
§The depths of the principal cavities in section H were as follows:

No. of cavity.	Depth.
1	1."1
2	0."9
3	0."5
4	0."5

After the removal of the eighth (H) section, the depth of the principal cavities in the breech end of the casting near the trunnions was measured.

	Depth: Inches.	
Cavity 1	4.0	(near axis of trunnions).
Cavity 2	0.6	
Cavity 3	0.3	
Cavity 4	0.7	
Cavity 5	1.5	
Cavity 6	0.75	

Up to the eighth (H) cut the core-arbor was found to be fused to the casting and broke off with each section. The fluting was destroyed and the iron around the core-arbor was chilled. After the removal of the eighth section the core-arbor was found to be movable, and was drawn out. The section of the arbor from the eighth cut to the next joint towards the muzzle—6 feet 2 inches long—was rejected. The two chase sections of the core-arbor were saved. One section was 12'.2" long, the other or muzzle section was 4'.4" long.

It was evident that the scaling of the core mixture from the arbor caused the violent ebullition of the melted iron during the casting.

The flaking off of this core let the melted iron come in contact with the barrel, and prevented the escape of the gases through the usual fluted channels.

The iron being in contact with the metallic arbor was rapidly chilled by the large volume of water passing through the core. The fluting on the exterior of the core barrel was completely destroyed and the wrought iron, was partially melted on the exterior, thus emphasizing the danger arising from the former use of cast-iron core barrels. Had this arbor been of cast iron instead of wrought iron, it would have dissolved in the melted bath and permitted the water to come in contact with the molten iron, producing an explosion and a large loss of life. In the excitement of the accident, the clamp-screws for the tripod were not loosened, and the heat expanded the arbor sufficient to cause it to buckle badly. The deflection of the arbor from the center of the casting at section "H" was about 3¾ inches.

PLATES.

Plate I, Fig. 1, is a tracing of the casting drawn to scale, showing the cracks and the details of cutting up.

Figs. 2 and 3 are the front and rear faces of the first or sinking head section (A). They are self explanatory.

It was deemed important to have photographs taken of the ends of the longitudinal cracks. Fig. 2 shows the positions of photographs Nos. 1, 2, 3, which are transmitted herewith. Nos. 1 and 2 show the broken end of the core-arbor. Nos. 2 and 3 show the cavities due to imprisoned gas.

No. 4 is an admirable representation of the rear end of the gun after first section was cut off, showing the chill around the core-arbor and the melting away of the wrought iron. No. 5 shows the new longitudinal crack and its branches, and the wrought-iron bands for holding the casting together, while cutting off sections. No. 6 shows the front-end of the original crack. No. 7 shows the front end of the second section (B). No. 8 shows the rear end of the third section (C), and on the upper and right-hand portions it shows the bubble holes or cavities caused by occluded gas.

The experience gained from this casting teaches that it is safe and prudent for the Government to reject any casting where an ebullition or escape of gas up through the melted metal takes place, no matter how good the casting appears upon the exterior or at the first section cut off.

FOURTH CASTING.

The fourth casting for the 12-inch tubed rifle was made April 5, 1886. It was cooled and removed from the pit by May 1 and is now in the lathe being bored and turned.

The details regarding furnace charges, melting, casting, and the cooling table are appended, marked Table II.

A glance at the cooling table will show that the company has again departed from the usual Rodman system of cooling. The core arbor was left in over 4 days (98 hours), and 40 gallons of water per minute was allowed to pass through the core barrel. The temperature fell in that time from 92° to 48½°. Then 2 hours was occupied in removing the core barrel, after which the bore was filled slowly with water and allowed to evaporate or pass off as steam for 115 hours. Just enough water was

admitted to supply the waste. For the next 7 hours a hand-pump was used to remove hot water from a point about 15 feet below the top, cold water being supplied at the top to keep the bore full.

During the 7 hours the temperature fell from 165 to 105°. The pumping was necessarily irregular, and no exact record could be kept of the amount of water passed through. The gun then stood 13 hours, and the temperature rose 57 to 162°, when the pumping was resumed for 2 hours, lowering the temperature to 96°.

A siphon was then inserted and operated for 9 hours, lowering temperature from 96 to 62°, or 34° in the first hour, and finally to 58°, or a fall of 38° in all.

Another rest of 13 hours sent the temperature up to 130°, when the bore was filled with cold water and the casting was then stripped.

No record was obtained of the amount of water used during the employment of the siphon.

RÉSUMÉ OF COOLING.

	Hours.
Core barrel in—40 gallons per minute	98
Removing core-barrel	2
Steam escaping from bore, waste supplied by cold water	115
Hand-pump removing water from 15 feet below surface, and cold water supplied to keep gun full	7
Gun filled with water, stood	13
Hand-pump used as before	2
Siphon used—no record of water admitted	9
Gun filled with water, stood	13
Total time cooling	259

The casting was removed to the lathe, and an initial tension-ring was taken out next the breech for test specimens.

PHYSICAL PROPERTIES OF FOURTH CASTING.

(a) *Initial tension-ring—breech.*

Exterior diameter of ring	inches	57.4
Exterior circumference of ring	do	180.3278
Interior diameter of ring	do	11.375
Interior circumference of ring	do	35.7357
Thickness of ring	do	3.1
Radial slot:		
Width before rupture—exterior	do	0.5
interior	do	0.45
Width after rupture—exterior	do	0.566
interior	do	0.52
Fractured section:		
Length	do	23.027
Thickness	do	0.118
Area	square inches	2.717
Extension per linear inch on exterior		0.000366
Initial tensin (3½ tons)	pounds	7,810

TABLE I.—*Statement of fabrication of ordnance, for the service of the United States, by the South Boston Iron Works, at the South Boston Foundry, under the supervision* of Capt. D. A. Lyle, Ordnance Department, U. S. A.*

[Third casting for the 12-inch B. L. R. gun with wire-wrapped steel tube. Cast October 16, 1885.]

CHARGE.

Iron used.

Grade of iron.	Furnaces.			
	No. 1.	No. 2.	No. 3.	Total.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
No. 1				
No. 2	15,000	15,000	15,000	45,000
No. 3, hard	17,000	17,000	17,000	51,000
No. 3, soft	16,000	16,000	16,000	48,000
Remelted	22,000	22,000	22,000	66,000
Total	70,000	70,000	70,000	210,000

Coal consumed.—Not furnished by company.
Character of test sticks.—Not taken.

RECORD OF CASTING.

Furnaces fired October 15, 1885, at 9 p. m.
Metal down October 16, 1885, at 6 a. m.
Time of melting, 9 hours.
Time in fusion, 6 hours, 45 minutes.
Gun cast October 16, 1885, at 12.44 p. m.
Time occupied in casting, 23 minutes.
Temperature of water entering core-barrel, 58 degrees.
Temperature of water leaving core-barrel at 2 p. m., 202 degrees.
Rate of water per minute, 50 gallons.
Fire kindled in pit, 12.42 p. m.
Temperature of pit in 8 hours and 37 minutes, 156 degrees.
Rate of water per minute changed at 4 a. m., October 21, 1885, to 36 gallons.
Temperature of water entering core-barrel, 58 degrees.
Temperature of water leaving core-barrel, 63 degrees.
Rate of water changed at 9 a. m., October 22, 1885, to 5 gallons.
Total time in cooling gun, 147½ hours.

*The entire operation and superintendence, and responsibility for the casting was under the direction of the founders, and the only supervision exercised by the inspectors was that required by the contract, so far as it provides for inspections at every stage of the manufacture.

TABLE I.—*Statement of fabrication of ordnance, &c.*—Continued.

COOLING TABLES.

Core-barrel.*

Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.
1	202	26	116	51	83	76	69	101	63	126	60
2	169	27	116	52	82	77	69	102	63	127	60
3	160	28	114	53	80	78	69	103	63	128	60
4	†150	29	110	54	78	79	69	104	63	129	60
5	149	30	108	55	78	80	69	105	63	130	60
6	148	31	106	56	76	81	69	106	63	131	60
7	190	32	105	57	76	82	67	107	63	132	60
8	‡148	33	104	58	76	83	67	108	63	133	60
9	147	34	102	59	76	84	66	109	63	134	60
10	144	35	100	60	74	85	66	110	63	135	60
11	142	36	99	61	74	86	66	111	63	136	60
12	138	37	97	62	74	87	66	112	§63	137	60
13	136	38	95	63	74	88	64	113	63	138	60
14	134	39	94	64	74	89	64	114	63	139	60
15	132	40	92	65	74	90	64	115	63	140	‖60
16	130	41	92	66	74	91	64	116	62	141	68
17	130	42	90	67	74	92	64	117	62	142	68
18	129	43	90	68	73	93	64	118	62	143	68
19	128	44	89	69	72	94	64	119	(¶)	144	69
20	127	45	89	70	72	95	64	120	(¶)	145	69
21	124	46	88	71	71	96	64	121	61	146	69
22	124	47	87	72	70	97	64	122	61	147	67
23	123	48	86	73	70	98	63	123	61	148	67
24	119	49	86	74	69	99	63	124	61		(**)
25	118	50	85	75	69	100	63	125	60		

*Core-barrel could not be withdrawn.
† Water rate changed to 40 gallons per minute.
‡ Water rate restored to 40 gallons per minute.
§ Water rate changed to 36 gallons per minute.
‖ Water rate changed to 5 gallons per minute.
¶ Not taken.
** Water off.

Additional details of cooling October 16, 1885.

Time.	Degrees.	Time.	Degrees.
12.41	58	7.00 p. m.	148
.44	58	7.45	144
.45	60	7.47	....
.48	63	8.10	190
.49	65	8.14	....
.50	68	8.19	....
.55	69	8.20	182
1.00 p. m.	70	8.25	....
1.01	72	8.27	....
1.02	74	8.30	....
1.03	76	8.35	134
1.04	77	8.40 p. m.	134
.05	80	8.45	132
.06	82	8.47	....
.07	84	8.50	136
.08	86	8.55	146
.09	87	9.00	148
.10	88	9.05	148
.11	90	9.30	148
1.42	202	10.00	147
2.00 p. m.	202	....	....
2.45	172	....	....

TABLE II.—*Statement of fabrication of ordnance for the service of the United States, by South Boston Iron Works, at the South Boston Foundry, under the supervision of Capt. D. A. Lyle, Ordnance Department, U. S. A.*

[Fourth casting of 12-inch B. L. R. gun, steel tube wire-wrapped. Cast April 5, 1888.]

CHARGE.

Iron used.

Grade of iron. Richmond—	Furnaces. No. 1.	No. 2.	No. 3.	Total.
	Pounds.	*Pounds*	*Pounds*	*Pounds.*
No. 2	15,000	15,000	15,000	45,000
No. 3 hard*	17,000	17,000	17,000	51,000
No. 3, soft	16,000	16,000	16,000	48,000
No. 3, Remelted	22,000	22,000	22,000	66,000
Total	70,000	70,000	70,000	210,000

*No. 3, hard, is classified as No. 4 at this foundry.

Coal consumed.

	Furnaces. No. 1.	No. 2.	No. 3.	Totals.
	Tons.	*Tons.*	*Tons.*	*Tons.*
Melting	11	11	11	33
Fusion	4	4	4	12
Total	15	15	15	45

RECORD OF CASTING.

Furnaces fired, April 4, at 9 p. m.
Metal down, April 5, at 8 a. m.
Time of melting, 11 hours.
Time in fusion, 4 hours 9 minutes.
Gun cast, April 5, at 12:42 p. m.
Time occupied in casting, 33 minutes.
Temperature of water entering core-barrel, 43 degrees.
Temperature of water leaving core-barrel, 88 degrees.
Rate of water per minute, 40 gallons.
Fire kindled in pit, April 5, 12:44 p. m.
Fire in pit went out, April 6, 7 p. m.
Fire in pit burned, 30¼ hours.
Water shut off, April 8, at 2 p. m.
Core-barrel removed, April 8, at 4 p. m.
Water entered gun, April 8, at 4 p. m.
*Rate of water per minute, ¼ gallon.
Temperature of water entering gun, 43 degrees.
Temperature of water leaving gun in — minutes, steam degrees.
Total time in cooling gun, 259 hours.

* Water did not flow through as usual, but just enough was supplied to compensate for evaporation.

TABLE II—*Statement of fabrication of ordnance, &c.*—Continued.

COOLING-TABLES.

Core-barrel.				Core-barrel removed.											
Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.
1	92	17	68	33	63	49	58	65	54½	81	51	97	49	239	62
2	82	18	67	34	63	50	57½	66	54	82	51	98	48½	240	62
3	81	19	67	35	62	51	57½	67	54	83	51	99	(*)	241	62
4	79	20	67	36	62	52	57	68	54	84	50	100	(†)(‡)	242	60
5	78	21	67	37	60	53	56½	69	53½	85	50	215	165	243	59
6	77	22	66	38	60	54	56½	70	53½	86	50	216	158	244	58
7	74	23	66	39	60	55	56	71	53½	87	50	217	154	245	58
8	72	24	65	40	59	56	56	72	53	88	50	218	152	246	58
9	70	25	65½	41	59	57	55½	73	53	89	50	219	132	(**)	......
10	71	26	65	42	59	58	55½	74	52½	90	50	220	122	259††	130
11	71	27	64½	43	60	59	55½	75	52½	91	50	221	112		
12	70	28	64	44	60	60	55	76	52	92	49½	222	105		
13	70	29	63	45	59½	61	55	77	52	93	49½	235§	162		
14	69	30	66	46	59	62	54½	78	52	94	49	236	120		
15	68	31	64	47	58½	63	54½	79	52	95	49	237	96		
16	68	32	64	48	58	64	55½	80	52	96	49	238‖	62		

* Hoisting harbor.
† Core-arbor removed.
‡ From the 100th hour to the 215th hour after casting (April 9, 4 p. m., to 11 a. m. April 14) 115, hours, just sufficient water was supplied to bore to compensate for the evaporation. The company then concluded to hasten the cooling by admitting water at the top and removing it by a pump 15 feet below the surface; pump stopped for the night at 6 p. m., April 14, 1886.
§ April 15, 7 a. m. (235th hour), temperature 162°; pump resumed work.
‖ Siphon replaced pump 238th hour.
** Siphon removed.
†† At 7 a. m., April 16, temperature of water 130° (259th hour); siphon started and used until warm water had been replaced by cold water. The company then commenced to remove the flask at 1 p. m. April 16, 1886.

MECHANICAL TESTS.

Specimens. Tenacity—	Hydrometer balance.		Density,
No. 11..........	Tangential ...	These specimens tested at South Boston Iron Works.	7.2737
12..............	....do		7.2284
13..............	....do		7.2675
Mean.....	....	....	7.2565

TENSILE STRENGTH.

Specimens.	Diameter of specimen.	Area of cross section.	Breaking weight.	Tenacity.
Tenacity No. 11.	Tested at South Boston Iron Works ...			28,737
Tenacity No. 12.				27,941
Tenacity No. 13.				29,138
Mean	....	....	....	28,605
	Inch.	*Sq. Inch.*	*Pounds.*	
Tension No. 1	1.129	1	*19,800	19,800
Tension No. 2	1.129	1	19,950	19,950
Mean	....	....	....	19,875

* Fracture granular; stellar spots of graphitic metal; these two specimens tested at Watertown Arsenal.

TABLE II—*Statement of fabrication of ordnance, &c.*—Continued.

INITIAL TENSION FROM BREECH.

Exterior diameter of ring.	Interior diameter of ring.	Thickness of ring.	Thickness of broken section.	Interior opening.	Exterior opening.	Circumference of exterior of ring.	Exterior per inch of circumference.	**Initial tension.**
Inches.	*Inches.*	*Inches.*	*Inch.*	*Inch.*	*Inch.*	*Inches.*	*Inch.*	*Pounds.*
57.4	11.375	3.1	0.118	.07	.066	180.3278	0.000366	7,810

TABLE III.—*Statement of fabrication of ordnance for the service of the United States, by South Boston Iron Works at the South Boston Foundry, under the supervision of Capt. D. A. Lyle, Ordnance Department, U. S. Army.*

[12-inch B. L. R. Mortar, cast July 30, 1886.]

CHARGE.

Iron used.

Grade of iron.	Furnaces. No. 1.	No. 2.	No. 3.	Total.
	Lbs.			*Lbs.*
No. 1				
No. 2	8,000			8,000
*No. 3 Hard	14,000			14,000
No. 3 Soft	12,000			12,000
Remelted	20,000			20,000
Total	54,000			54,000

*No. 3 hard is classified as No. 4 at this foundry.

CHARGE.

Coal Consumed.

	Furnaces. No. 1.	No. 2.	No. 3	Total.
Melting	8½ tons			8½ tons
Fusion	4½ tons			4½ tons
Total	13 tons			13 tons

Character of test sticks.

Furnaces.	No. 1.	No. 2.	No. 3.	Basin.
Iron	Mottled, hard, crystalline, hard points, somewhat earthy in places.	Mottled, hard, earthy look gone.	Mottled, hard, earthy look gone.	None used.

TABLE III.—*Statement of fabrication of ordnance, &c.*—Continued.

RECORD OF CASTING.

Furnaces fired July 30, at 3 a. m.
Metal down at 11 a. m.
Time of melting, 8 hours.
Time in fusion, 4h. 36m.
Gun cast July 30, at 3.49 p. m.
Time occupied in casting, 13 minutes.
Temperature of water entering core-barrel, 71 degrees.
Temperature of water leaving core-barrel, 105 degrees.
Rate of water per minute, 21 gallons.
Fire kindled in pit July 30, 1886, 4 p. m.
Fire in pit went out August 1, 1886, 1.15 a. m.
Fire in pit burned 33¼ hours.
Water shut off August 3, at 9 a. m.
Core-barrel removed August 1, at 9.40 a. m.
Water entered gun August 1, at 10 a. m.
Rate of water per minute, 10 gallons.
Temperature of water entering gun, 71 degrees.
Temperature of water leaving gun in 20 minutes, 153 degrees.
Total time in cooling gun, 88 hours.

COOLING TABLES.

Core-barrel.						Core-barrel removed.					
Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.
1	100	15	86	29	83	†41	153	57	81	73	74
2	99½	16	86	30	83	42	152	58	80	74	74
3	97	17	86	31	83	43	148	59	80	75	74
4	95	18	85½	32	82	44	143	60	79	76	74
5	93	19	85½	33	82	45	129	61	79	77	74
6	92	20	85½	34	82	46	119	62	79	78	74
7	91	21	85½	35	81	47	111	‡63	82	79	73
8	90	22	85½	36	81	48	105	§64	78	80	73
9	90	23	85½	37	80	49	100	65	78	81	73
10	89	24	85½	38	78	50	90	66	77	82	73
11	89	25	85	39	78	51	88	67	76	83	73
12	88	26	85	40	78	52	85	68	75	84	73
13	88	27	84			53	83	69	74	85	73
14	87	28	84			54	83	70	74	86	73
						55	82	71	74	87	73
						56	82	72	74	88	‖73

* No. 3 hard is classified as No. 4 at this foundry.
† Rate of water changed to 10 gallons per minute.
‡ Variation most likely due to changes in hydrant pressure.
§ Temperature a few minutes before was 82°.
‖ Water shut off.

ADDITIONAL DETAILS OF COOLING.

Date.	Hour.	Minutes after tapping.	Temperature of water leaving core-barrel.
			Degrees.
July 30	3.36	0	71
30	3.38	2	73
30	3.44	8	74
30	3.46	10	77
30	3.47	11	79
30	3.48	12	83
30	3.49	*13	88
30	3.52	16	98
30	3.53	17	100
30	3.55	19	101
30	4 P. M.	24	105
30	5 P. M.	†84	100

* Gun cast.
† 60 minutes after casting.

REMARKS.—The entire operation and superintendence and responsibility for the casting was under the direction of the founders, and the only supervision exercised by the inspectors was that required by the contract, so far as it provides for inspections at every stage of the manufacture.

THIRD CASTING For 12" RIFLE, Wire Wrapped, Steel Tube.

[Cast breech up, Oct 16, 1886]

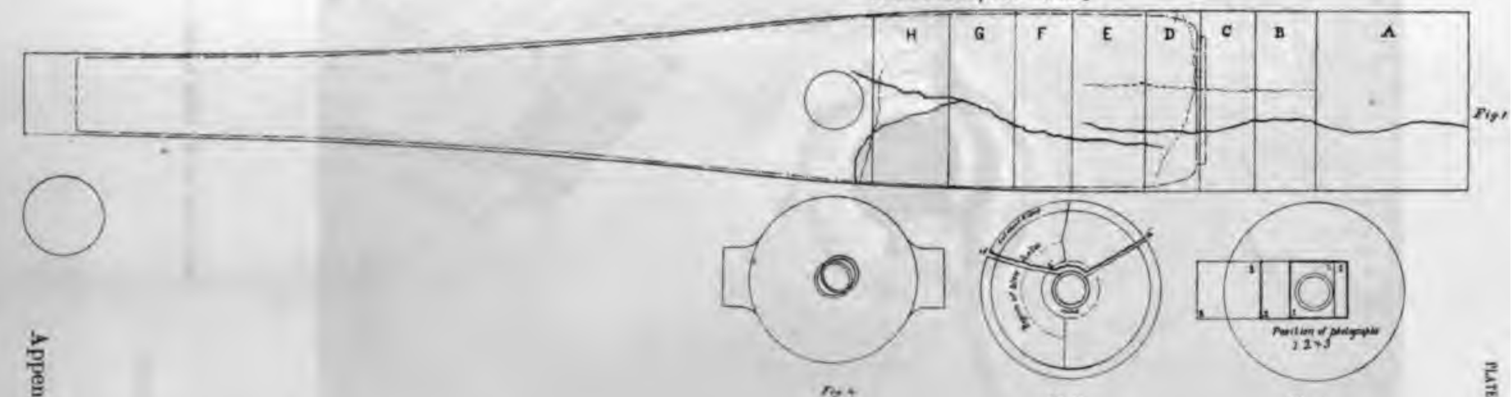
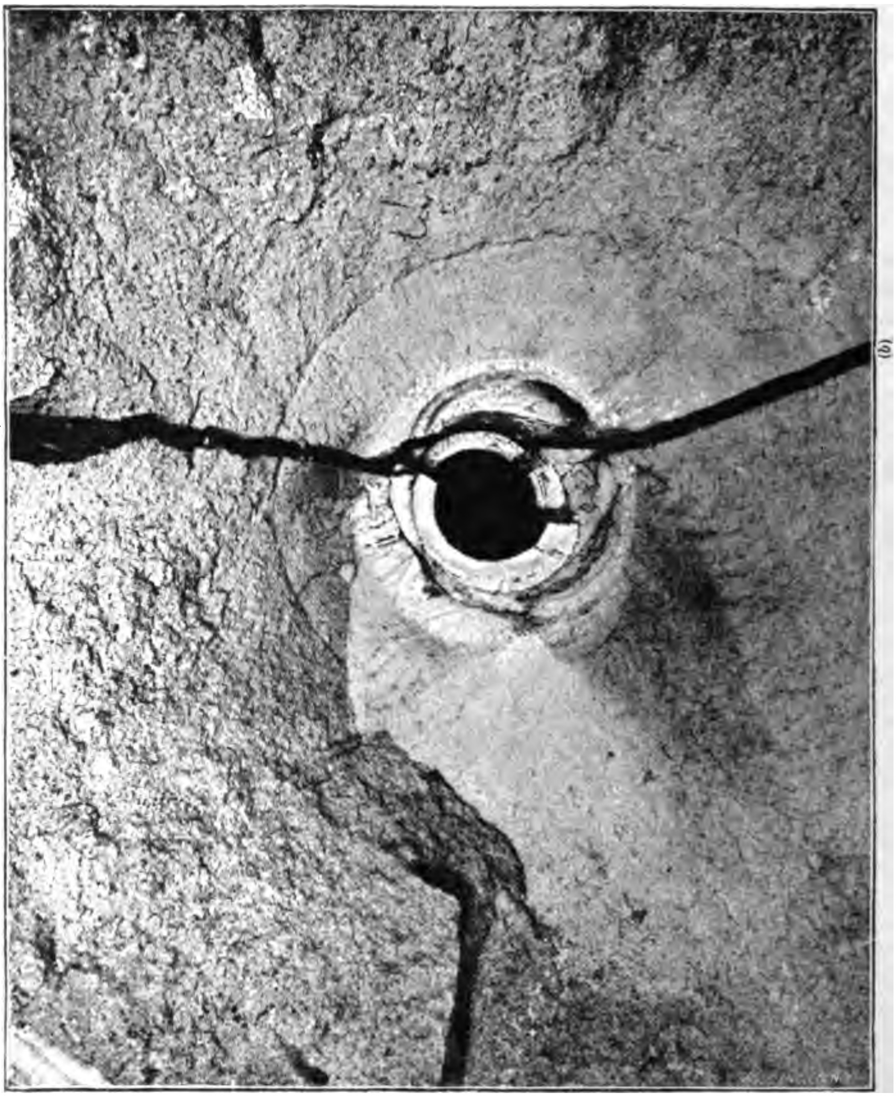


Fig 4. Fig 3. Fig 2.



(*a*). Original crack. (*b*). New crack.

No. 8. REAR END OF 3D SECTION.

APPENDIX 23.

T SHOWING THE NATURE AND PROGRESS OF THE WORK DONE THE ORDNANCE DEPARTMENT, U. S. ARMY, BY THE MIDVALE COMPANY, DURING THE FISCAL YEAR ENDING JUNE 30, 1886.

BY LIEUT. F. E. HOBBS, ORDNANCE DEPARTMENT.

MIDVALE STEEL WORKS,
Philadelphia, Pa., July 20, 1886.

IEF OF ORDNANCE, U. S. A.,
Washington, D. C.:

Complying with your instructions, I have the honor to submit owing report, showing the nature and progress of the work done Ordnance Department by the Midvale Steel Company during al year ending June 30, 1886.*

ng the time specified the Midvale Steel Company continued work he following contracts with the department, viz:

orgings for fifty steel tubes, breech-cups, and muzzle-collars for onverted rifles.

orgings for the parts of twenty-five 3.2-inch steel breech-loading ns.

ube, jacket, and trunnion-hoop, for an 8-inch steel breech-loade.

xperimental trunnion hoop for an 8-inch steel breech-loading rifle.

also undertook to execute the following contracts for steel for gun ction, viz:

orgings for the parts of a 5-inch steel breech-loading rifle.

ne forged hoop for a 10-inch cast-iron wire-wound rifle.

ive forged hoops for a 10-inch steel breech-loading rifle.

ne hundred and four rolled steel billets.

orgings for the breech mechanism of an 8-inch and a 10-inch steel loading rifle, and a 12 inch breech-loading rifled mortar.

Twelve rolled hoops, and one forged trunnion-hoop for a 12-inch loading rifled mortar.

is date those numbered 2, 4, and 6, are completed, and those ed 1, 3, 5, 7, 8, 9 and 10 are still in hand.

GS FOR FIFTY STEEL TUBES, BREECH-CUPS, AND MUZZLE-COLLARS FOR 8-INCH CONVERTED RIFLES.

equired dimensions and physical qualities of these forgings, with count of their manufacture and summaries of the results of the specimens taken from them, were given in the report for the fiscal

y all information relative to manufacture is omitted in this report, as The Steel Company desire that all details of this nature shall be considered con-, and for the use of the Department only.

year ending June 30, 1885. At that date fifty-six tubes had been forged, of which twenty-seven had been accepted as to physical qualities, and six had been rejected.

At the present writing sixty-four tubes have been forged, of which forty-seven have been accepted as to physical qualities, and fifteen have been finally rejected.

Of the accepted tubes twenty-six were accepted on the results of the test of the first specimens submitted; eleven were retreated and retested, three of the eleven being twice retreated and retested; and ten were retested simply; two of the ten being twice retested, and one being three times retested.

The manufacture has been considerably delayed, owing to the fact which was noted in the former report that the rough forgings have to be sent to another firm to be rough turned and bored before treatment, and also because so much testing has been done. This latter cause has sometimes kept one forging in question for a number of months before its final rejection, and hence before the work of replacement could be commenced. The retesting of a forging when it is not accepted from any cause which can probably be overcome, as shown by the results of test of the first set of specimens presented, is, of course, only fair to the manufacturer, but, as stated, it necessarily delays completion of a contract if the retested piece is finally rejected.

The percentage of rejections of these tube forgings has been quite large, in fact much larger than any manufacturer could well afford in current work, showing how much experience and well considered previous plans are required before the supply of material of the high character required for gun construction can be successfully undertaken. The reason why so many of the tubes did not show excellent results of test will not be discussed, as a full discussion here would necessitate a publication of many points which The Midvale Steel Company regard as confidential. It is my opinion, however, disregarding the points of manufacture which cause failure, but which were improved upon during the life of the contract, that the principal cause of the large number of rejections was the too small weight of the ingot used. I believe that now this company could take a similar contract and, making the tubes from larger ingots, save a very large percentage of the final rejections and considerable of the retreatment and retesting required in filling this contract.

The contract specifications as to the physical qualities of these tubes were fully met by the results of test of the first set of specimens presented in the following cases.

Results of tensile tests of tangential specimens from ends of tubes for 8-inch converted rifles.

[Length of specimen, 3 inches; sectional area, 0.25 of a square inch.]

Number of tube.	Breech or muzzle.	Number of specimen.	Position of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
				Pounds.	*Inch.*	*Pounds.*	*Per ct.*	*Per cent.*		
1	Breech..	1	Inside ..	44,000	.001333	73,920	30.0	57.0	7.8607	11.81
1	.. do ..	2	Outside.	43,000	.001433	79,080	25.0	47.2	......	......
1	...do ...	3	Middle .	40,000	.001200	76,340	23.33	41.9	......	......
1	Muzzle .	1	Inside ..	45,000	.001400	83,000	24.33	44.6	7.8592	18.99
1	...do ...	2	Outside.	42,000	.001400	78,640	27.0	54.6	......	......
1	. do ...	3	Middle .	41,000	.001300	77,280	25.0	54.6	......	......
2	Breech	1	Inside ..	38,000	.001267	80,960	21.67	47.2	7.8569	13.38
2	.. do ...	2	Outside	41,000	.001467	79,800	24.33	49.7	......	......
2	. do ..	3	Middle .	39,000	.001467	76,680	23.33	49.7	......	......
2	Muzzle .	1	Inside ..	49,000	.001667	89,040	20.33	47.2	7.8538	16.31
2	.. do ...	2	Outside	44,000	.001433	81,680	26.33	49.7	......	......
2	do ...	3	Middle	47,000	.001767	90,160	20.00	39.2	......	......
11	Breech .	1	Inside	43,000	.001333	81,440	22.33	49.7	7.8539	13.40
11	...do ...	2	Outside	45,000	.001533	84,680	22.0	54.6	......	......
11	do ..	3	Middle	41,000	.001267	79,800	26.0	54.6	......	......
11	Muzzle	1	Inside .	42,000	.001333	81,660	23.33	49.7	7.8525	12.48
11	...do ...	2	Outside	40,000	.001100	80,600	22.0	49.7	......	......
11	..do ..	3	Middle	45,000	.001300	84,160	24.33	44.6	......	......
12	Breech .	4	Inside ..	39,000	.001300	76,680	26.33	52.2	......	......
12	....do ...	5	Outside	41,000	.001233	78,320	21.0	47.2	......	......
12	...do ...	6	Middle	40,000	.001400	75,000	29.33	47.2	......	......
12	Muzzle .	8	Inside ..	43,000	.001400	79,040	24.0	44.6	......	......
12	....do ...	9	Outside.	41,000	.001467	78,840	23.0	52.2	......	......
12	....do ...	10	Middle .	40,000	.001267	75,280	25.67	44.6	......	......
13	Breech..	8	Inside ..	41,000	.001300	75,520	26.67	54.6	......	......
13	...do ...	9	Outside.	44,000	.001467	78,800	26.0	52.2	......	......
13	...do ...	10	Middle	40,000	.001400	77,000	24.33	52.2	......	......
13	Muzzle	4	Inside ..	43,000	.001400	76,800	25.67	47.2	......	......
13	....do .	5	Outside	41,000	.001267	77,840	23.33	54.6	......	......
13	. do ...	6	Middle .	46,000	.001633	80,400	24.67	49.7	......	......
18	Breech..	13	Inside ..	42,000	.001467	81,200	24.0	49.7	......	......
18	...do .	14	Outside	37,000	.001267	77,600	24.0	44.6	......	......
18	do ...	15	Middle	42,000	.001633	80,800	23.67	47.2	7.8533	16.99
18	Muzzle .	13	Inside	39,000	.001433	81,200	21.0	30.6	......	......
18	....do ...	14	Outside.	43,000	.001567	84,000	22.0	44.6	...	......
18	....do ...	15	Middle .	42,000	.001533	83,600	21.0	47.2	7.8492	14.19
21	Breech..	1	Inside ..	44,000	.001400	81,400	22.67	57.0	7.8561	13.08
21	... do .	2	Outside.	42,000	.001233	80,160	24.0	57.0	......	......
21	do ..	3	Middle .	41,000	.001367	80,000	24.67	47.2	......	......
21	Muzzle .	1	Inside ..	46,000	.001533	86,000	20.33	47.2	7.8537	14.26
21	....do ...	2	Outside.	45,000	.001467	82,760	23.0	52.2	......	......
21	do ...	3	Middle	43,000	.001367	82,600	22.33	49.7		......
24	Breech..	1	Inside ..	44,000	.001400	76,800	26.0	50.8	7.8632	11.81
24	....do ...	2	Outside	41,000	.001400	80,480	26.67	52.2	......	......
24	do ..	3	Middle	41,000	.001267	79,160	24.67	54.6	......	......
24	Muzzle .	1	Inside ..	45,000	.001533	86,360	23.33	47.2	7.8593	14.54
24	do .	2	Outside.	43,000	.001567	83,280	25.0	47.2	......	......
24	Muzzle	3	Middle..	41,000	.001367	82,440	23.67	49.7	......	......
25	Breech	1	Inside ..	43,000	.001400	78,800	24.33	49.7	7.8594	12.60
25	...do ...	2	Outside .	44,000	.001433	81,820	23.67	47.2	......	......
25	...do ..	3	Middle..	45,000	.001467	81,760	26.67	49.7	......	......
25	Muzzle .	1	Inside...	45,000	.001433	84,080	20.33	47.2	7.8551	13.59
25	.. do ...	2	Outside	43,000	.001400	77,280	22.0	52.2	......	......
25	....do ...	3	Middle..	44,000	.001433	86,080	23.0	44.6	......	......
28	Breech .	1	Inside ..	45,000	.001367	80,240	24.0	52.2	7.8667	14.54
28	...do ...	2	Outside	40,000	.001233	82,000	22.67	49.7	......	......
28	...do ..	3	Middle .	43,000	.001267	82,000	22.33	49.7	......	......
28	Muzzle .	1	Inside...	46,000	.001367	83,960	20.67	52.2	7.8606	15.20
28	....do...	2	Outside .	44,000	.001367	84,560	25.33	52.2	......	......
28	....do .	3	Middle..	43,000	.001400	84,200	24.67	49.7	......	......
38	Breech .	1	Inside .	44,000	.001400	77,640	25.0	54.6	......	......
38	...do .	2	Outside	46,000	.001467	86,200	23.67	49.7	......	......
38	....do ...	3	Middle..	41,000	.001400	76,560	26.67	52.2	......	......
38	Muzzle .	1	Inside...	42,000	.001300	82,440	24.33	49.7	......	......
38	....do ...	2	Outside .	40,000	.001333	79,840	23.0	49.7	......	......
38	....do ...	3	Midule..	44,000	.001467	85,200	25.67	47.2	......	......

The Department has been quite lenient towards the manufacturer in accepting tubes which fairly, but not fully filled the contract specifications, where leniency seemed perfectly proper after full consideration of all the details of manufacture; to what extent is partially shown by the results of the test of the following tubes, accepted on the results of the test of the first set of specimens presented:

Results of tensile tests of tangential specimens from ends of tubes for 8-inch converted rifles.

[Length of specimen, 3 inches; sectional area, 0.25 of a square inch.]

Number of tubes.	Breech or Muzzle.	Number of specimen.	Position of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
				Pounds.	*Inch.*	*Pounds.*	*Per ct.*	*Per cent.*		
30	Breech	1	Inside	39, 000	.001300	74, 400	23. 33	54. 6	7. 8601	12. 78
30	...do	2	Outside	38, 000	.001133	75, 240	22. 67	49. 7		
30	do	3	Middle	37, 000	.001133	74, 560	27. 0	57. 0		
30	Muzzle	1	Inside	46, 000	.001400	79, 280	22. 67	41. 9	7. 8564	14. 06
30	..do	2	Outside	42, 000	.001333	79, 640	24. 0	49. 7		
30	...do	3	Middle	42, 000	.001300	79, 240	19. 0	41. 9		
43	Breech	1	Inside	40, 000	.001267	74, 800	25. 0	49. 7	7. 8571	12. 72
43	...do	2	Outside	40, 000	.001400	76, 040	24. 0	52. 2		
43	do	3	Middle	39. 000	.001200	75, 040	29. 0	54. 6		
43	Muzzle	1	Inside	37, 000	.001333	78, 440	23. 33	39. 2	7. 8587	12. 78
43	..do	2	Outside	38, 000	.001233	75, 920	24. 33	39. 2		
43	do	3	Middle	37, 000	.001200	78, 680	20. 33	21. 4		
35	Breech	1	Inside	37, 000	.001233	73, 040	27. 67	49. 7	7. 8552	11. 49
35	..do	2	Outside	41, 000	.001267	75, 800	25. 33	52. 2		
35	.do	3	Middle	38, 000	.001300	75, 200	26. 0	52. 2		
35	Muzzle	1	Inside	46, 000	.001533	78, 000	21. 33	41,9	7. 8517	12. 65
35	.do	2	Outside	44, 000	.001433	79, 200	26. 33	49. 7		
35	..do	3	Middle	40. 000	.001267	77, 480	26. 33	49. 7		
34	Breech	1	Inside	39, 000	.001233	73, 880	23. 67	44. 6	7. 8564	12. 66
34	...do	2	Outside	41, 000	.001267	78, 840	21. 0	44. 6		
34	do	3	Middle	40. 000	.001333	75, 160	25. 67	47. 2		
34	Muzzle	1	Inside	43, 000	.001300	79, 480	22. 67	41. 9	7. 8536	15. 20.
34	...do	2	Outside	41, 000	.001167	76, 600	26. 0	49. 7		
34	..do	3	Middle	40, 000	.001300	78, 800	25. 67	44. 6		
33	Breech	1	Inside	42, 000	.001333	78, 880	21. 67	44. 6	7. 8604	12. 72
33	...do	2	Outside	41, 000	.001267	78, 840	24. 0	54. 6		
33	do	3	Middle	40, 000	.001233	80, 240	25. 67	49. 7		
33	Muzzle	1	Inside	52, 000	.001667	88, 600	20. 67	41. 9	7. 8574	17. 17
33	...do	2	Outside	45, 000	.001400	81, 560	22. 67	36. 4		
33	...do	3	Middle	43, 000	.001400	80, 640	18. 33	39. 2		
45	Breech	1	Inside	40, 000	.001367	74, 040	27. 0	44. 6		
45	....do	2	Outside	41, 000	.001400	76, 480	24. 33	47. 2		
45	do	3	Middle	39, 000	.001300	72, 360	26. 67	49. 7		
45	Muzzle	1	Inside	43, 000	.001467	80, 600	22. 33	41. 9		
45	..do	2	Outside	40, 000	.001367	75, 880	22. 33	49. 7		
45	.do	3	Middle	35, 000	.001133	72, 840	24. 67	33. 5		
42	Breech	1	Inside	38, 000	.001233	73, 600	24. 0	36. 4	7. 8590	12. 86
42	....do	2	Outside	39, 000	.001367	74. 440	28. 33	57. 0		
42	..do	3	Middle	35, 000	.001233	71, 520	26. 67	44. 6		
42	Muzzle	1	Inside	40, 000	.001400	79, 800	22. 0	47. 2	7. 8544	14. 98
42	do	2	Outside	42, 000	.001367	80, 560	24. 33	47. 2		
42	do	3	Middle	36, 000	.001533	76, 080	20. 0	21. 4		
3	Breech	1	Inside	43, 000	.001367	79, 360	22. 33	41. 9	7. 8625	11. 81
3	....do	2	Outside	42, 000	.001333	80, 880	19. 67	49. 7		
3	...do	3	Middle	40, 000	.001300	75, 640	25. 0	52. 2		
3	Muzzle	1	Inside	44, 000	.001267	85, 760	20. 33	41. 9	7. 8551	12. 46
3	....do	2	Outside	43, 000	.001433	81, 880	23. 67	47. 2		
3	do	3	Middle	46, 000	.001500	82, 800	27. 33	52. 2		
22	Breech	1	Inside	38, 000	.001167	74, 640	26. 33	47. 2	7. 8545	11. 18
22	... do	2	Outside	39, 000	.001200	78, 000	23. 33	49. 7		
22	....do	3	Middle	40, 000	.001300	78, 080	22. 33	44. 6		
22	Muzzle	1	Inside	39, 000	.691300	75, 240	22. 33	57. 0	7. 8562	11. 75
22	..do	2	Outside	39, 000	.001100	75, 360	24. 67	54. 6		
22	do	3	Middle	37, 000	.001233	74, 120	24. 0	61. 5		
8	Breech	7	Inside	35, 000	.001167	70, 200	26. 0	44. 6		

Results of tensile tests of tangential specimens from ends of tubes for 8-inch converted rifles—Continued.

Number of tubes.	Breech or Muzzle.	Number of specimen.	Position of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
				Pounds.	*Inch.*	*Pounds.*	*Per ct.*	*Per cent.*		
8	Breech..	8	Outside.	37,000	.001400	73,520	25.0	47.2	....	....
8	....do....	9	Middle..	41,000	.001367	76,080	23.0	33.5	....	....
8	Muzzle	4	Inside ..	35,000	.001133	75,160	21.67	39.2	....	....
8	....do....	5	Outside.	37,000	.001267	77,640	23.33	36.4	....	....
8	do ...	6	Middle..	41,000	.001400	80,060	23.33	39.2	....	....
20	Breech..	1	Inside ..	35,000	.001133	72,520	23.0	52.2	7.8576	11.44
20	....do....	2	Outside.	38,000	.001267	77,280	23.0	49.7	....	....
20	....do....	3	Middle..	37,000	.001267	75,000	26.67	47.2	....	....
20	Muzzle	1	Inside ..	44,000	.001167	81,360	24.0	41.9	7.8559	12.84
20	....do....	2	Outside	42,000	.001433	80,200	19.67	33.5	....	....
20	....do....	3	Middle ..	41,000	.001400	79,400	25.33	52.2	....	....
40	Breech	1	Inside ..	40,000	.001367	72,720	26.67	47.2	7.8556	11.92
40	....do....	2	Outside	40,000	.001433	74,960	25.33	44.6	....	....
40	....do	3	Middle..	35,000	.001233	71,680	23.33	49.7	....	....
40	Muzzle	1	Inside ..	34,000	.001067	72,800	24.0	41.9	7.8528	11.59
40	....do....	2	Outside	36,000	.001233	77,120	23.67	24.6	....	....
40	....do....	3	Middle..	35,000	.001133	76,000	23.67	36.4	....	....
32	Breech	7	Inside ..	35,000	.001167	72,440	29.33	49.7	....	....
32	....do....	8	Outside.	36,000	.001233	76,960	25.67	54.6	....	....
32	....do....	9	Middle.	35,000	.001200	74,800	25.33	49.7	....	....
32	Muzzle	10	Inside ..	41,000	.001367	79,920	20.33	49.7	....	....
32	....do....	11	Outside.	42,000	.001433	82,000	22.0	47.2	....	....
32	do ...	12	Middle	38,000	.001167	76,600	22.33	49.7	....	....
47	Breech..	1	Inside	42,000	.001433	74,440	27.67	54.6	....	....
47	....do....	2	Outside.	39,000	.001233	70,520	28.33	54.6	....	....
47	do	3	Middle .	38,000	.001233	69,200	28.0	54.6	....	....
47	Muzzle	1	Inside ..	39,000	.001233	72,240	29.33	49.7	....	....
47	do ..	2	Outside	41,000	.001400	72,680	26.67	44.6	....	....
47	do .	3	Middle .	35,000	.001133	73,560	23.33	36.4	....	....
29	Breech..	1	Inside ..	40,000	.001300	78,160	25.67	52.2	7.8585	10.24
29	..do....	2	Outside	40,000	.001133	77,840	26.0	52.2	....	....
29	..do....	3	Middle .	41,000	.001400	77,200	23.33	52.2	....	....
29	Muzzle .	1	Inside .	47,000	.001467	85,280	18.33	49.7	7.8553	12.08
29	....do....	2	Outside	44,000	.001367	83,080	23.33	49.7	....	....
29	....do....	3	Middle...	43,000	.001400	81,440	22.33	47.2	....	....

Tubes which were retested and accepted gave the following final results, either fully or fairly filling the specifications:

Results of tensile tests of tangential specimens from ends of tubes for 8-inch converted rifles

[Length of specimen, 3 inches; sectional area, 0.25 of a square inch.]

Number of tube.	Breech or muzzle.	Number of specimen.	Postion of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
				Pounds.	*Inch.*	*Pounds.*	*Per ct.*	*Per cent.*		
5	Breech..	1	Inside ...	40,000	.001233	80,000	14.00	24.6	....	....
5	. do ...	2	Outside	43,000	.001400	79,160	24.67	49.7	7.8563	12.78
5	do ...	3	Middle .	38,000	.001267	79,360	27.67	49.7	....	....
5	Muzzle	1	Inside ..	45,000	.001300	78,760	29.67	49.7	....	....
5	....do ..	2	Outside.	46,000	.001467	82,360	23.67	49.7	7.8551	13.85
5	....do ...	3	Middle .	45,000	.001433	78,640	24.33	54.6	....	....
5	Breech..	4	Inside .	44,000	.001400	82,960	16.67	36.4	....	....
5	....do ...	5	....do...	44,000	.001400	81,240	23.0	47.2	....	....

Results of tensile tests of tangential specimens from ends of tubes for 8-inch converted rifles—Continued.

Number of tubes.	Breech or muzzle.	Number of specimen.	Position of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
				Pounds.	*Inch.*	*Pounds.*	*Per ct.*	*Per cent.*		
5	Breech	6	Outside	40,000	.001233	80,560	23.67	47.2	....	......
6	Muzzle	1	Inside	40,000	.001433	81,600	27.33	52.2	7.8571	14.12
6	...do	2	Outside	39,000	.001400	78,800	26.67	49.7	....	......
6	...do	3	Middle	41,000	.001700	81,240	23.33	49.7	....	......
6	Breech	4	Inside	35,000	.001100	74,080	27.67	52.2	....	......
6	...do	5	Outside	40,000	.001333	77,920	21.0	36.4	....	......
6	...do	6	Middle	36,000	.001233	77,000	24.83	52.2	....	......
9	..do	1	Inside	45,000	.001433	81,160	23.67	47.2	7.8528	12.60
9	...do	2	Outside	46,000	.001500	84,840	19.67	36.4	....	......
9	...do	3	Middle	43,000	.001367	80,160	23.33	36.4	....	......
9	Muzzle	1	Inside	51,000	.001700	91,040	22.67	49.7	7.8532	16.28
9	do	2	Outside	50,000	.001700	90,480	22.0	44.6	....	......
9	do	3	Middle	45,000	.001400	87,360	22.33	44.6	....	......
9	Breech	4	Inside	44,000	.001433	77,120	25.33	47.2	....	......
10	..do	1	..do	41,000	.001300	80,120	23.67	47.2	7.8551	11.82
10	...do	2	Outside	43,000	.001367	80,880	23.67	52.2	....	......
10	do	3	Middle	40,000	.001333	78,320	17.33	47.2	....	......
10	Muzzle	1	Inside	46,000	.001433	84,360	24.0	44.6	7.8536	13.58
10	.do	2	Outside	47,000	.001433	86,960	25.67	47.2	....	......
10	..do	3	Middle	46,000	.001200	85,520	22.67	44.6	....	......
10	Breech	4	Inside	45,000	.001300	82,600	21.33	52.2	....	......
10	.do	5	Outside	44,000	.001500	85,160	23.67	47.2	....	......
14	..do	4	Inside	43,000	.001367	73,840	24.0	44.6	....	......
14	...do	5	Outside	40,000	.001267	75,960	26.67	49.7	....	......
14	...do	6	Middle	42,000	.001300	76,240	23.0	33.5	....	......
14	Muzzle	4	Inside	45,000	.001400	79,760	19.67	36.4	....	......
14	do	5	..do	49,000	.001500	83,000	19.0	49.7	....	......
15	Breech	11	do	43,000	.001433	80,720	22.0	49.7	....	......
15	....do	12	Outside	42,000	.001367	81,840	22.33	54.6	....	......
15	....do	13	Middle	42,000	.001467	80,760	20.33	49.7	....	......
15	Muzzle	11	Inside	45,000	.001533	87,680	22.33	49.7	....	......
15	.do	12	Outside	47,000	.001600	87,920	18.33	49.7	....	......
15	...do	13	Middle	45,000	.001700	86,080	19.33	47.2	....	......
16	...do	4	Inside	39,000	.001233	77,680	20.33	41.9	....	......
16	...do	5	Outside	42,000	.001433	8,440	24.67	52.2	....	......
16	do	6	Middle	40,000	.001133	78,000	23.33	49.7	....	......
16	Breech	10	Inside	45,000	.001600	77,200	25.67	57.0	....	......
16	..do	11	Outside	38,000	.001400	74,000	25.33	49.7	....	......
16	..do	12	Middle	39,000	.001333	76,000	26.0	52.2	....	......
17	do	4	Inside	41,000	.001400	76,280	24.33	57.0	....	......
17	.do	5	do	43,000	.001367	77,680	26.67	54.6	....	......
17	...do	6	Middle	3,000	.001167	74,800	20.0	54.6	....	......
17	..do	7	...do	39,000	.001233	75,680	23.33	54.6	....	......
17	Muzzle	4	Inside	37,000	.001200	76,000	12.0	18.3	....	......
17	...do	5	Outside	36,000	.001200	76,680	21.33	39.2	....	......
17	..do	6	Middle	35,000	.001267	75,920	26.33	49.7	....	......
17	do	7	do	40,000	.001267	80,280	20.67	39.2	....	......
19	Breech	10	Inside	41,000	.001400	76,720	23.33	44.6	....	......
19	...do	11	Outside	37,000	601200	75,800	23.33	41.9	....	......
19	....do	12	Middle	38,000	.001333	75,280	23.67	52.2	....	......
19	Muzzle	9	Inside	40,000	.001533	78,800	21.33	57.0	....	......
19	.do	10	Outside	46,000	.001600	83,600	20.67	49.7	....	......
19	.do	11	Middle	45,000	.001600	82,240	20.33	39.2	....	......
23	Breech	1	Inside	44,000	.001467	78,160	23.0	49.7	7.8541	9.20
23	do	2	Outside	41,000	.001333	77,440	20.33	27.6	....	......
23	..do	3	Middle	40,000	.001267	74,000	28.67	54.6	....	......
23	Muzzle	1	Inside	45,000	.001433	82,000	19.67	39.2	7.8511	11.70
23	do	2	Outside	43,000	.001400	80,440	25.0	47.2	....	......
23	..do	3	Middle	43,000	.001400	82,880	24.07	47.2	....	......
26	Breech	8	Inside	43,000	.001467	76,200	24.33	57.0	....	......
26	....do	9	Outside	43,000	.001467	77,800	26.33	59.3	....	......
26	....do	10	Middle	42,000	.001533	78,080	27.0	57.0	....	......
26	Muzzle	8	Inside	44,000	.001433	83,600	18.67	49.7	....	......
26	..do	9	Outside	42,000	.001567	81,760	22.33	49.7	....	......
26	...do	10	Middle	42,000	.001400	81,640	22.67	47.2	....	......
27	Breech	4	Inside	42,000	.001433	78,320	20.0	39.2	....	......
27	....do	5	Outside	39,000	.001300	77,520	26.67	54.6	....	......
27	....do	6	Middle	40,000	.001367	77,240	25.67	54.6	....	......

Results of tensile tests of tangential specimens from ends of tubes for 8-inch converted rifles—Continued.

Number of tubes.	Breech or muzzle.	Number of specimen.	Position of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
				Pounds.	*Inch.*	*Pounds.*	*Per ct.*	*Per cent.*		
27	Muzzle	4	Inside	43,000	.001433	78,400	20.33	49.7	....	....
27	do	5	Outside	43,000	.001500	82,440	19.33	39.2	....	....
27	do	7	Inside	42,000	.001433	82,880	22.67	47.2	....	....
27	Muzzle	8	Outside	45,000	.001667	82,720	23.67	49.7	....	....
27	do	9	Middle	41,000	.001500	80,200	16.0	18.3	....	....
31	Breech	1	Inside	35,000	.001033	72,240	26.0	41.9	7.8618	11.33
31	do	2	Outside	85,000	.001100	74,080	26.67	44.6	....	....
31	do	3	Middle	34,000	.001100	71,840	24.67	41.9	....	....
31	Muzzle	4	Inside	41,000	.001367	76,720	24.0	47.2	....	....
31	do	5	Outside	41,000	.001300	77,400	23.0	47.2	....	....
31	do	6	Middle	39,000	.001367	76,000	22.0	33.5	....	....
31	do	7	do	39,000	.001333	75,680	21.33	47.2	....	....
36	Breech	1	Inside	38,000	.001267	72,200	27.0	54.6	7.8577	11.92
36	do	2	Outside	42,000	.001300	78,280	27.0	44.6	....	....
36	do	3	Middle	39,000	.001200	75,440	24.67	44.6	....	....
36	Muzzle	4	Inside	38,000	.001267	79,360	23.0	39.2	....	....
36	do	5	Middle	38,000	.001200	77,000	22.33	44.6	....	....
36	do	6	do	40,000	.001367	76,000	22.33	31.9	....	....
37	Breech	4	Inside	43,000	.001400	72,240	24.33	44.6	....	....
37	do	5	Outside	47,000	.001500	78,000	23.33	39.2	....	....
37	do	6	Middle	41,000	.001433	73,960	21.33	33.5	....	....
37	Muzzle	4	Inside	43,000	.001367	72,120	27.67	47.2	....	....
37	do	5	Outside	43,000	.001400	74,800	28.33	54.6	....	....
37	do	6	Middle	41,000	.001267	73,560	27.33	44.6	....	....
39	Breech	1	Inside	46,000	.001467	75,480	27.0	57.0	....	....
39	do	2	Outside	41,000	.001433	73,400	26.0	39.2	....	....
39	do	3	Middle	42,000	.001433	74,720	24.67	47.2	....	....
39	Muzzle	4	Inside	43,000	.001433	76,000	24.33	54.6	....	....
39	do	5	Outside	44,000	.001400	77,400	20.0	41.9	....	....
39	do	6	Middle	42,000	.001433	75,760	22.33	30.6	....	....
41	Breech	4	Inside	39,000	.001400	74,600	27.0	57.0	....	....
41	do	5	Outside	43,000	.001400	78,240	24.33	54.6	....	....
41	do	6	Middle	40,000	.001333	75,400	26.0	57.0	....	....
41	Muzzle	4	Inside	44,000	.001500	77,120	16.67	21.4	....	....
41	do	5	Outside	44,000	.001500	76,240	24.33	47.2	....	....
41	do	6	Middle	43,000	.001367	77,240	23.33	49.7	....	....
41	do	7	Inside	43,000	.001400	76,000	20.0	41.9	....	....
41	do	8	Outside	39,000	.001267	75,640	27.33	52.2	....	....
41	do	9	Middle	38,000	.001233	76,560	17.67	24.6	....	....
46	Breech	1	Inside	44,000	.001433	75,680	24.67	57.0	....	....
46	do	2	Outside	40,000	.001367	74,760	25.67	52.2	....	....
46	do	3	Middle	39,000	.001300	73,040	27.0	57.0	....	....
46	do	4	Inside	43,000	.001433	75,240	28.67	59.3	....	....
46	Muzzle	7	do	40,000	.001300	76,800	23.0	52.2	....	....
46	do	8	Outside	35,000	.001033	73,240	21.67	36.4	....	....
46	do	9	Middle	34,000	.001133	73,120	23.33	30.6	....	....
48	Breech	7	Inside	49,000	.001733	81,900	21.67	47.2	....	....
48	do	8	do	50,000	.001800	84,950	25.0	51.9	....	} *
48	do	9	do	49,000	.001700	82,500	23.50	43.3	....	} *
48	do	10	Outside	54,000	.001900	85,500	25.0	49.1	....	} *
48	Muzzle	10	Inside	41,000	.001233	80,200	20.0	52.2	....	....
48	do	11	Outside	42,000	.001433	78,720	25.67	49.7	....	....
48	do	12	Middle	42,000	.001600	82,160	22.67	36.4	....	....
49	Breech	1	Inside	36,000	.001167	71,200	20.67	49.7	....	....
49	do	2	Outside	35,000	.001133	71,600	26.67	49.7	....	....
49	do	3	Middle	43,000	.001400	78,320	25.0	49.7	....	....
49	Muzzle	4	Inside	41,000	.001433	78,640	22.33	41.9	....	....
49	do	5	Outside	37,000	.001267	73,920	21.67	27.6	....	....
49	do	6	Middle	40,000	.001267	78,880	20.67	30.6	....	....

* Two-inch specimens.

While tubes finally rejected gave the following results:

Results of tensile tests of tangential specimens from ends of tubes for 8-inch converted rifles.

[Length of specimen, 3 inches; sectional area, 0.25 of a square inch.]

Number of tube.	Breech or muzzle.	Number of specimen.	Position of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
				Pounds.	*Inch.*	*Pounds.*	*Per ct.*	*Per cent.*		
7	Breech..	1	Inside..	44,000	.001400	83,800	13.00	18.3	7.8528	13.65
7	....do ...	2	Outside.	41,000	.002100	82,600	11.67	15.0	......	.....
7	....do ..	3	Middle.	43,000	.001333	84,320	23.33	41.9	......	.....
7	Muzzle .	1	Inside ..	45,000	.001133	88,240	23.67	44.6	7.8542	14.98
7	...do ...	2	Outside	45,000	.001367	88,000	24.0	49.7	......	.....
7	....do ..	3	Middle .	47,000	.001467	87,200	21.67	47.2	......	.....
7	Breech.	4	Inside ..	37,000	.001167	70,720	18.0	21.4	......	.....
7	....do ...	5	....do ...	34,000	.001167	69,920	13.33	18.3	......	.....
7	do ...	6	....do ...	37,000	.001167	68,000	10.67	15.0	......	.....
New 7	Muzzle .	4	....do ...	41,000	.001267	78,880	26.0	44.6	......	.....
New 7	.. do ...	5	Outside	39,000	.001300	76,440	27.0	49.7	......	....
New 7	....do ...	6	Middle .	37,000	.001167	79,160	23.67	44.6	......	.....
New 7	Breech.	7	Inside .	33,000	.001100	70,280	26.67	49.7	......	.....
New 7	.. do ...	8	Outside	33,000	.001133	73,960	20.0	30.6	......	.....
New 7	do .	9	Middle .	32,000	.001167	71,520	26.0	36.4	......	.....
New 7	Muzzle .	7	Inside .	39,000	.001333	77,680	22.67	44.6	......	.....
New 7	.. do ..	8	Outside	37,000	.001267	78,200	20.67	44.6	...	.....
New 7	do ..	9	Middle .	38,000	.001333	77,520	20.0	41.9	......	.....
New 7	Breech	10	Inside	40,000	.001433	80,800	18.0	39.2	......	.....
New 7	. do ..	11	Outside	43,000	.001500	84,840	18.67	44.6	......	.....
New 7	do .	12	Middle	38,000	.00[illegible]00	76,560	20.33	44.6	......	.....
New 7	Muzzle.	10	Inside ..	46,000	.001533	82,800	20.33	49.7	......	.....
New 7	do .	11	Outside	41,000	.001467	78,360	19.67	44.6	......	.....
New 7	do	12	Middle .	38,000	.001267	80,240	19.0	52.2	....	....
8	Breech .	1	Inside .	40,000	.001333	75,6[illegible]0	11.33	21.4	7.8607	11.18
8	...do ...	2	Outside.	43,000	.001400	82,080	24.0	49.7	......	.....
8	do ..	3	Middle .	40,000	.001233	82,000	20.67	27.6	......	.....
8	Muzzle	1	Inside	47,000	.001533	86,000	25.33	41.9	7.8566	14.40
8	. do ..	2	Outside	42,000	.001400	81,040	22.33	49.7	......	.....
8	. do .	3	Middle .	45,000	.001400	82,120	22.33	52.2	......	.....
8	Breech .	4	Inside .	40,000	001267	80,160	17.0	39.2	......	.....
8	....do ..	5	..do .	41,000	.001367	80,080	17.0	44.6	......	....
8	. do ..	6	Outside	39,000	.001233	77,920	23.67	52.2	......	.....
12	....do ..	1	Inside	44,000	.001500	82,000	21.0	47.2	7.8553	12.84
12	...do	2	Outside	41,000	.001200	80,600	22.33	54.6	......	.....
12	do ..	3	Middle	39,000	.001200	79,280	22.67	49.7	......	.....
12	Muzzle .	1	Inside ...	41,000	.001300	80,160	18.00	41.9	7.8352	12.48
12	.. do ...	2	Outside	41,600	.001167	78,880	22.67	52.2	......	.....
12	..do ..	3	Middle	33,000	.001133	59,680	4.67	11.8	......	.....
12	... do ...	4	Inside.	37,000	.001167	67,200	5.33	11.8	......	.....
12	....do ...	5	Outside	35,000	.001133	67,000	7.0	11.8	......	.....
12	....do ...	6	Middle	32,000	.001100	58,560	6.0	11.8	......	.....
12	...do ..	7	..do ..	39,000	.001267	80,200	22.67	47.2	......	.....
13	Breech.	1	Inside ..	37,000	.001233	75,280	22.33	41.9	7.8584	11.49
13	....do ...	2	Outside	40,000	.001433	78,840	14.67	21.4	......	.....
13	.. do ...	3	Middle	37,000	.001100	75,720	19.67	33.5	......	.....
13	Muzzle	1	Inside	44,000	.001400	83,320	26.67	49.7	7.8549	13.59
13	...do ...	2	Outside	0,000	.001367	79,640	25.0	47.2	......	....
13	...do ...	3	Middle .	43,000	.001367	83,600	26.67	47.2	......	.....
13	Breech..	4	Inside ..	39,000	.001233	78,000	21.67	48.9	......	.....
13	...do ..	5	Outside	35,000	.001133	75,480	23.33	41.5	......	.....
13	...do ...	6	Middle .	35,000	.001100	74,720	16.67	30.6	......	.....
13	...do .	7	. do	35,000	.001067	74,400	26.67	47.2	......	.....
15	....do .	1	Inside ..	40,000	.001367	72,000	10.0	30.6	7.8581	12.30
15	.. do ..	2	Outside.	42,000	.001500	80,400	25.33	49.7	......	.....
15	....do ..	3	Middle	37,000	.001300	73,600	11.67	24.6	......	.....
15	Muzzle .	1	Inside ..	46,000	.001467	81,320	19.0	49.7	7.8562	12.25
15	....do	2	Outside	43,000	.001400	81,240	26.33	52.2	......	.....
15	. do .	3	Middle	40,000	.001333	78,160	23.33	54.6	......	.....
15	Breech..	4	Inside	42,000	.001367	78,000	23.33	49.7	......	.....
15	....do ...	5	Outside	37,000	.001300	7,720	22.67	47.2	......	.....
15	...do ...	6	Middle	37,000	001267	68,800	6.33	11.8	......	.....
15	...do ..	7	. do .	39,000	.001267	76,720	18.0	44.6	......	.....
15	Muzzle	4	Inside ..	45,000	.001267	78,480	21.0	54.6	......	.....
15	.. do .	5	Outside	43,000	.001300	80,240	24.33	44.6	......	.....

Results of tensile tests of tangential specimens from ends of tubes, &c.—**Continued.**

Number of tube.	Breech or muzzle.	Number of specimen.	Position of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
				Pounds.	*Inch.*	*Pounds.*	*Per ct.*	*Per cent.*		
15	Muzzle	6	Middle	40,000	.001333	77,600	19.0	52.2	....	......
15	...do	7	..do	43,000	.001367	82,360	21.33	47.2	....	......
16	Breech	1	Inside	41,000	.001400	78,400	20.33	52.2	7.8586	11.59
16	...do	2	Outside	44,000	.001467	83,800	21.33	36.4	....	......
16	...do	3	Middle	42,000	.001533	82,900	13.67	21.4	....	......
16	Muzzle	1	Inside	48,000	.001333	87,880	18.0	33.5	7.8390	12.80
16	...do	2	Outside	43,000	.001433	81,900	24.0	54.6	....	......
16	...do	3	Middle	49,000	.001233	76,560	15.67	52.2	....	......
18	Breech	1	Inside	41,000	.001267	82,800	19.0	33.5	7.8569	12.42
18	...do	2	Outside	44,000	.001400	85,120	20.33	41.9	....	......
18	...do	3	Middle	41,000	.001367	81,640	25.33	44.6	....	......
18	Muzzle	1	Inside	51,000	.001700	89,280	22.33	41.9	7.8548	14.98
18	...do	2	Outside	51,000	.001867	92,200	21.33	47.2	....	......
18	...do	3	Middle	48,000	.001533	89,520	22.67	47.2	....	......
18	Breech	4	Inside	31,000	.000800	71,680	28.0	44.6	....	......
18	...do	5	Outside	37,000	.001267	74,480	25.67	33.5	....	......
18	...do	6	Middle	34,000	.001000	71,920	14.67	21.4	....	......
18	...do	7	Inside	31,000	.001000	70,840	27.67	41.9	....	......
18	...do	8	Outside	35,000	.001167	73,040	31.0	49.7	....	......
18	...do	9	Middle	32,000	.001100	70,800	14.33	21.4	....	......
New 18	Breech	7	Inside	38,000	.001167	72,560	25.67	44.6	....	......
New 18	...do	8	Outside	37,000	.001200	73,120	24.33	49.7	....	......
New 18	...do	9	Middle	40,000	.001367	75,000	24.0	41.9	....	......
New 18	Muzzle	4	Inside	38,000	.001233	73,840	16.0	21.4	....	......
New 18	...do	5	Outside	41,000	.001367	76,360	17.67	21.4	....	......
New 18	...do	6	Middle	36,000	.001133	72,600	19.67	27.6	....	......
New 18	Breech	10	Inside	41,000	.001367	76,440	20.33	36.4	....	......
New 18	...do	11	Outside	44,000	.001500	82,840	20.67	44.6	....	......
New 18	...do	12	Middle	42,000	.001367	78,800	20.33	41.9	....	......
New 18	Muzzle	7	Inside	44,000	.001500	80,800	13.67	30.6	....	......
New 18	...do	8	Outside	41,000	.001400	82,800	17.0	30.6	....	......
New 18	...do	9	Middle	39,000	.001333	76,000	19.33	44.6	....	......
New 18	...do	10	Inside	43,000	.001600	81,920	14.0	24.6	....	......
New 18	...do	11	Outside	44,000	.001600	82,240	20.67	44.6	....	......
New 18	...do	12	Middle	40,000	.001400	77,840	18.67	49.7	....	......
19	Breech	1	Inside	36,000	.001200	74,480	15.83	30.6	7.8622	11.89
19	...do	2	Outside	39,000	.001333	78,280	23.0	47.2	....	......
19	do	3	Middle	35,000	.001133	70,400	9.33	21.4	....	......
19	Muzzle	1	Inside	41,000	.001433	84,880	20.67	33.5	7.8600	14.06
19	...do	2	Outside	45,000	.001300	86,760	18.0	30.6	....	......
19	...do	3	Middle	43,000	.001400	83,160	21.33	41.9	....	......
19	Breech	4	Inside	35,000	.001033	74,640	20.67	39.2	....	......
19	...do	5	Outside	39,000	.001267	78,800	22.67	47.2	....	......
19	...do	6	Middle	35,000	.001133	76,480	21.33	36.4	....	......
19	Muzzle	4	Inside	44,000	.001533	80,080	22.33	44.6	....	......
19	...do	5	Outside	45,000	.001567	80,840	23.0	41.9	....	......
26	Breech	1	Inside	40,000	.001233	75,200	20.33	27.6	7.8571	12.96
26	...do	2	Outside	41,000	.001267	77,920	23.0	36.4	....	......
26	do	3	Middle	40,000	.001100	78,200	27.0	52.2	....	......
26	Muzzle	1	Inside	44,000	.001533	81,880	18.0	21.4	7.8561	16.15
26	...do	2	Outside	40,000	.001300	83,760	24.33	49.7	....	......
26	do	3	Middle	41,000	.001267	83,000	25.67	49.7	....	......
26	Breech	4	Outside	40,000	.001233	77,000	10.67	15.0	....	......
26	Muzzle	4	Inside	45,000	.001400	84,760	22.33	49.7	....	......
32	Breech	1	Inside	41,000	.001333	78,000	27.0	52.2	7.8540	14.47
32	...do	2	Outside	41,000	.001267	80,800	23.67	44.6	....	......
32	do	3	Middle	42,000	.001433	81,040	21.33	36.4	....	......
32	Muzzle	1	Inside	42,000	.001433	80,840	17.33	24.6	7.8502	16.13
32	...do	2	Outside	43,000	.001300	80,720	21.0	44.6	....	......
32	do	3	Middle	47,000	.001533	86,000	19.33	41.9	....	......
32	Breech	4	Inside	38,000	.001100	75,960	26.0	41.9	....	......
32	...do	5	Outside	37,000	.001167	75,800	23.33	39.2	....	......
32	do	6	Middle	38,000	.001300	76,720	26.0	47.2	....	......
32	Muzzle	4	Inside	47,000	.001533	81,160	14.33	21.4	....	......
32	...do	5	Outside	45,000	.001533	82,080	21.33	41.9	....	......
32	...do	6	Middle	42,000	.001400	80,760	16.67	27.6	....	......
32	...do	7	Inside	34,000	.001167	72,640	18.33	27.6	....	......
32	...do	8	Outside	38,000	.001167	75,840	18.33	33.5	....	......
32	...do	9	Middle	35,000	.001167	73,520	22.67	21.4	....	......
44	Breech	1	Inside	40,000	.001367	75,400	17.67	47.2	....	......

Results of tensile tests of tangential specimens from ends of tubes, &c.—**Continued.**

Number of tube.	Breech or muzzle.	Number of specimen.	Position of specimen	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
				Pounds	*Inch.*	*Pounds*	*Per ct.*	*Per cent.*		
44	Breech..	2	Outside.	41,000	.001433	77,600	26.0	52.2	....	......
44	...do ..	3	Middle .	41,000	.001400	78,000	26.33	52.2	....	......
44	Muzzle .	1	Inside ..	46,000	.001567	81,640	15.67	21.4	....	......
44	....do ..	2	Outside	43,000	.001433	78,080	24.33	49.7	....	......
44	..do ...	3	Middle	40,000	.001300	76,400	17.67	24.6	....	......
New 44	Breech..	4	Inside	41,000	.001400	81,000	22.67	52.2	....	......
New 44	....do ...	5	Outside.	45,000	.001367	83,000	22.33	49.7	....	......
New 44	...do ...	6	Middle	41,000	.001400	76,000	25.67	52.2	....	......
New 44	Muzzle	4	Inside ..	42,000	.001433	80,000	21.0	33.5	....	......
New 44	...do ..	5	Outside.	47,000	.001400	81,000	14.33	18.3	....	......
New 44	...do ...	6	Middle .	41,000	.001467	81,200	23.33	47.2	....	......
New 44	....do ...	7	Inside ..	42,000	.001500	80,080	15.67	21.4	....	......
New 44	....do ..	8	Outside	44,000	.001567	82,000	20.33	30.6	....	......
New 44	..do ..	9	Middle	42,000	.001533	80,640	21.67	49.7	....	......
New 44	..do ..	10	Inside ..	43,000	.001500	82,000	16.67	21.4	....	......
New 44	...do ..	11	Outside	44,000	.001533	81,040	23.0	44.6	....	......
New 44	...do ...	12	Middle .	42,000	.001400	80,000	24.0	47.2	....	......
New 44	. do ...	13	Inside ..	45,000	.001567	82,040	20.67	41.9	....	......
New 44	...do ..	14	Outside	43,000	.001467	81,520	23.33	30.6	....	......
New 44	..do ...	15	Middle .	42,000	.001467	79,600	18.33	27.6	7.8618	14.90
50	Breech .	1	Inside ..	39,000	.001233	74,200	23.67	49.7	....	......
50	....do ..	2	Outside	39,000	.001267	76,200	22.67	30.4	....	......
50	....do ...	3	Middle .	3[illegible],000	.001167	71,480	26.67	36.4	....	......
50	Muzzle .	1	Inside ..	36,000	.001133	76,040	19.33	24.6	....	......
50	....do ...	2	Outside	38,000	.001233	77,680	23.33	36.4	....	......
50	...do ..	3	Middle .	43,000	.001400	80,240	15.67	18.3	....	......
50	Breech..	4	Inside ..	35,000	.001267	72,640	22.33	21.4	....	......
50	....do ...	5	Outside.	28,000	.001300	73,560	29.0	57.0	....	......
50	..do ...	6	Middle	37,000	.001233	74,880	23.33	33.5	....	......
50	Muzzle .	4	Inside ..	38,000	.001267	76,490	20.33	33.5	....	......
50	....do ...	5	Outside	38,000	.001167	76,600	25.67	47.2	....	......
50	...do ...	6	Middle .	37,000	.001133	73,440	23.67	33.5	....	......
50	Breech..	7	Inside ..	46,000	.001500	80,000	13.0	21.4	....	......
50	...do ...	8	Outside	53,000	.001867	87,200	19.67	41.9	....	......
50	..do ..	9	Middle .	49,000	.001750	83,500	22.50	43.3	....	......
50	Muzzle	7	Inside ..	50,000	.001667	86,000	14.67	18.3	....	......
50	....do ...	8	Outside	46,000	.001500	84,000	18.0	24.6	....	......
50	....do ...	9	Middle	49,000	.001733	82,400	7.0	11.8	....	......

The present condition of manufacture of the three tubes still to be delivered is as follows, viz, one is to be retreated, one has been forged and is now being rough turned and bored, and one is to be forged.

Forgings for the parts of twenty-five 3.2-*inch steel breech-loading field guns.*

The rough-finished dimensions of these forgings, with the required physical qualities of the metal, and summaries of the results of the test of specimens from the few forgings which had at that time been completed, were given in the report for the fiscal year ending June 30, 1885.

The work on these forgings progressed quite satisfactorily, the principal delay being that arising from an attempt of the company to utilize for some of these small forgings parts of forgings of larger size which had been rejected on account of the poor results shown in the test of one or more of the specimens cut from one of the ends. The poor qualities seemed, however, in nearly every case to obtain throughout the whole of the larger forging, necessitating the replacement of quite a number of these smaller forgings. Some time was also lost in experimenting in the manufacture of trunnion hoops. Fifteen jackets were

either condemned by the company without presentation to the Department for test or were rejected by the Department after test.

Some trouble was caused by warping of tubes, and in several cases the forgings were scant of the rough-finished dimensions required. In all such cases the forging was accepted with the proviso that the Midvale Steel Company would assume all risk of failure to finish to the required dimensions, if such failure was due to the scant rough-finished dimensions.

The physical qualities obtained in these forgings are summarized in the following tables:

Results of tensile tests of tangential specimens from ends of tubes for 3.2-inch steel breech-loading field guns.

[Length of specimen, 2 inches sectional area, 0.2 of a square inch.]

Number of tube.	Breech or muzzle.	Number of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.	Specific gravity.
			Pounds.	*Inch.*	*Pounds.*	*P. cent.*	*P. cent.*	
*1	Breech	1	50,000	.001600	85,350	24.0	51.9	7.8615
*1	...do	2	49,000	.001800	84,900	20.0	40.3	....
*1	Muzzle	1	48,000	.001450	85,200	15.0	34.0	....
*1	...do	2	43,000	.001300	80,100	29.0	49.1	....
*1	...do	3	43,000	.001400	81,050	25.0	40.3	....
*1	...do	4	48,000	.001550	84,400	15.0	23.9	....
1	Breech	4	56,000	.002000	93,400	18.50	40.3	....
1	...do	5	55,000	.001900	96,000	20.50	37.1	....
1	Muzzle	5	54,000	.001850	94,600	26.50	43.3	....
1	...do	6	53,000	.001800	91,900	23.50	43.3	....
2	Breech	1	49,000	.001650	88,500	24.50	43.3	....
2	...do	2	44,000	.001250	86,250	25.0	46.2	....
2	Muzzle	1	48,000	.001700	85,350	24.0	46.2	....
2	...do	2	48,000	.001700	86,600	25.0	46.2	....
*3	Breech	1	58,000	.001800	95,100	23.50	49.1	7.8705
*3	...do	2	54,000	.001650	92,750	23.0	49.1	....
*3	Muzzle	1	54,000	.001750	92,900	12.0	13.2	....
*3	...do	2	54,000	.001750	93,400	19.50	43.3	....
*3	...do	3	49,000	.001650	80,700	28.50	51.9	....
*3	...do	4	39,000	.001550	74,550	28.50	49.1	....
3	Breech	4	52,000	.001650	93,750	23.50	46.2	....
3	...do	5	54,000	.001750	97,450	18.0	34.0	....
3	Muzzle	5	56,000	.002100	99,100	22.0	40.3	....
3	...do	6	56,000	.001750	100,800	17.0	34.0	....
4	Breech	1	46,000	.001400	84,900	25.0	49.1	7.8724
4	...do	2	44,000	.001300	80,400	20.50	37.1	....
4	Muzzle	1	53,000	.001750	90,050	21.50	49.1	....
4	...do	2	50,000	.001650	86,850	22.50	46.2	....
5	Breech	1	49,000	.001800	85,150	22.50	51.9	....
5	...do	2	46,000	.001850	85,700	23.50	51.9	....
5	Muzzle	1	55,000	.001900	84,500	22.50	54.6	....
5	...do	2	53,000	.001800	86,050	20.50	49.1	....
6	Breech	1	54,000	.001700	89,350	21.0	40.3	7.8702
6	...do	2	56,000	.001800	89,950	25.50	51.9	....
6	Muzzle	1	51,000	.001500	87,100	24.50	51.9	....
6	...do	2	53,000	.001700	89,300	23.50	51.9	....
7	Breech	1	58,000	.001900	92,450	23.50	49.1	....
7	...do	2	57,000	.001950	91,950	17.0	46.2	....
7	Muzzle	1	50,000	.001600	83,100	24.0	49.1	....
7	...do	2	52,000	.001850	86,600	22.50	49.1	....
8	Breech	1	49,000	.001650	91,600	22.50	46.2	7.8730
8	...do	2	49,000	.001650	91,300	20.0	43.3	....
8	Muzzle	1	53,000	.001850	87,350	22.0	46.2	....
8	...do	2	54,000	.001800	88,700	24.50	43.3	....
9	Breech	1	56,000	.001900	90,450	24.50	46.2	....
9	...do	2	59,000	.002100	93,050	20.0	43.3	....
9	Muzzle	1	56,000	.001900	92,400	21.0	43.3	....
9	...do	2	55,500	.001850	90,100	21.50	46.2	....
10	Breech	1	50,000	.001550	86,300	27.0	49.1	7.8707
10	...do	2	50,000	.001830	87,550	23.50	37.1	....
10	Muzzle	1	49,000	.001550	87,500	20.0	49.1*	....

* Rejected.

Results of tensile tests of tangential specimens from ends of tubes, &c.—Continued.

Number of tube.	Breech or muzzle.	Number of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.	Specific gravity.
			Pounds.	*Inch.*	*Pounds.*	*P. cent.*	*P. cent.*	
10	Muzzle ..	2	50,000	.001550	89,050	20.0	46.2	....
11	Breech ..	1	49,000	.001700	90,550	21.50	49.1	7.8657
11	...do	2	51,000	.001650	92,400	25.0	49.1	....
11	Muzzle .	1	50,000	.001650	92,450	20.50	43.3	....
11	...do . ..	2	55,000	.001900	91,950	21.50	46.2	....
12	Breech ..	1	54,000	.001650	92,250	20.50	43.8	7.8654
12	.. do	2	54,000	.001550	89,050	22.50	49.1	....
12	Muzzle ..	1	52,000	.001700	90,400	22.50	40.3	7.8601
12	...do	2	53,000	.001700	89,400	19.0	40.3	....
*13	Breech ..	1	53,000	.001800	91,950	19.50	46.2	7.8684
*13	...do	2	53,000	.001850	90,300	19.0	46.3	....
*13	Muzzle ..	1	53,000	.001800	95,550	18.50	43.3	7.8590
*13	...do	2	59,000	.002000	98,400	17.0	40.3	....
13	Breech ..	4	49,000	.001750	84,850	22.0	46.2	....
13	...do	5	50,000	.001700	86,200	21.50	49.1	....
13	Muzzle ..	3	43,000	.001500	80,000	24.0	40.3	....
13	...do	4	41,000	.001300	79,800	21.50	40.3	....
*14	Breech ..	1	57,000	.002150	96,200	16.50	30.7	7.8589
*14	...do	2	58,000	.001850	100,000	15.0	34.0	....
*14	Muzzle ..	1	55,000	.001700	90,400	19.0	40.3	....
*14	...do	2	54,000	.001800	91,800	20.0	46.2	....
14	Breech ..	4	47,000	.001600	86,850	20.0	37.1	....
14	...do	5	48,000	.001600	88,250	19.0	37.1	....
14	Muzzle ..	3	47,000	.001750	82,250	21.50	49.1	....
14	...do	4	49,000	.001500	84,750	21.0	43.3	....
15	Breech ..	1	53,000	.001800	85,850	21.0	43.3	....
15	.. do . ..	2	55,000	.001800	88,900	24.0	46.2	....
15	Muzzle ..	1	51,000	.001700	84,000	23.0	43.3	....
15	...do	2	50,000	.001650	82,500	20.50	46.2	....
†16	Breech ..	1	52,000	.001850	89,400	7.0	9.5	....
†16	.. do	2	49,000	.001550	83,750	6.0	9.5	....
†16	Muzzle ..	1	51,000	.001750	86,900	23.50	43.8	....
†16	...do	2	50,000	.001500	86,600	20.0	43.8	....
†16	Breech ..	4	51,000	.001700	91,950	19.0	37.1	....
†16	...do	5	49,000	.001750	90,100	7.50	9.5	....
16	...do	7	47,000	.001500	91,100	20.50	37.1	....
16	.. do ...	8	47,000	.001500	90,750	21.50	43.8	....
16	Muzzle ..	3	47,000	.001800	87,150	24.0	49.1	....
16	...do	4	45,000	.001650	85,050	21.50	46.2	....
17	Breech ..	1	49,000	.001750	84,600	23.50	40.8	....
17	.. do	2	49,000	.001650	82,850	21.50	40.8	....
17	Muzzle ..	1	44,000	.001600	81,250	21.50	43.8	....
17	...do	2	45,000	.001700	80,950	22.50	46.2	....
18	Breech ..	1	48,000	.001700	87,600	21.0	43.8	....
18	...do ...	2	50,000	.001700	89,200	18.50	37.1	....
18	Muzzle ..	1	41,000	.001350	79,250	20.50	43.3	....
18	.. do . ..	2	44,000	.001300	82,400	20.50	49.1	....
19	Breech ..	1	52,000	.001750	87,450	23.0	43.8	7.8767
19	.. do . ..	2	50,000	.001800	87,450	21.50	43.8	....
19	Muzzle ..	1	48,000	.001500	88,700	24.00	43.8	....
19	...do	2	50,000	.001650	89,450	23.50	40.3	....
20	Breech ..	1	50,000	.001550	88,500	20.50	46.2	7.8665
20	...do	2	52,000	.001850	92,250	21.00	43.8	....
20	Muzzle ..	1	49,000	.001550	86,450	25.00	51.9	....
20	...do	2	49,000	.001570	88,800	21.00	43.8	....
21	Breech .	1	51,000	.001800	88,450	23.50	46.2	....
21	...do	2	48,000	.001650	86,500	21.00	46.2	....
21	Muzzle ..	1	47,000	.001650	86,050	20.50	46.2	....
21	...do . ..	2	50,000	.002000	90,250	18.50	40.8	....
‡22	Breech ..	1	49,000	.001300	60,300	23.50	40.8	7.8592
‡22	.. do	2	39,000	.001200	79,900	26.00	43.8	....
‡22	Muzzle ..	1	45,000	.001450	83,400	26.00	46.2	....
‡22	.. do	2	53,000	.001600	89,950	24.00	43.3	....
‡22	Breech ..	4	41,000	.001300	75,500	27.50	51.9	....
‡22	.. do	5	42,000	.001300	77,400	24.00	34.0	....
‡22	Muzzle ..	3	52,000	.001650	85,050	25.00	46.2	....
‡22	.. do	4	53,000	.001760	87,450	27.00	46.2	....
23	Breech ..	1	53,000	.001850	94,050	23.00	40.3	7.8601
23	...do	2	52,000	.001600	93,000	24.50	40.3	....

* Not accepted on these results; reannealed.
† Rejected.
‡ Not accepted on these results; retempered and annealed.

***Results of tensile tests of tangential specimens from ends of tubes, &c.*—Continued.**

Number of tube.	Breech or muzzle.	Number of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.	Specific gravity.
			Pounds.	*Inch.*	*Pounds.*	*P. cent.*	*P. cent.*	
23	Muzzle ..	1	56, 000	.001700	93, 350	20.00	40.3	....
23	.. do	2	57, 000	.001850	93, 900	21.00	43.3	....
*24	Breech ..	1	40, 000	.001250	77, 300	26.00	46.2	....
*24	...do	2	39, 000	.001000	78, 300	26.50	40.3	....
*24	Muzzle ..	1	48, 000	.001550	85, 850	24.00	46.2	....
*24	.. do	2	53, 000	.001850	90, 300	23.00	40.3	....
*24	Breech ..	4	42, 000	.001400	75, 300	22.00	49.1	....
*24	...do	5	48, 000	.001500	81, 500	24.50	49.1	....
*24	Muzzle ..	3	47, 000	.001400	80, 600	20.50	49.1	....
*24	.. do	4	54, 000	.002000	84, 100	23.50	46.2	....
†24	Breech ..	7	55, 000	.001850	90, 400	21.50	46.2	....
†24	...do	8	49, 000	.001650	88, 250	21.50	46.2	....
†24	Muzzle ..	5	46, 000	.001550	88, 950	24.00	49.1	....
25	Breech ..	1	48, 000	.001550	85, 750	24.50	51.9	7.8606
25	.. do	2	47, 000	.001450	83, 950	25.50	51.9	....
25	Muzzle ..	1	52, 000	.001700	88, 500	25.50	51.9	....
25	...do	2	45, 000	001400	83, 000	21.50	51.9	....

* Not accepted on these results; retempered and annealed.
† Tube No. 22 also accepted on these results.

Results of compression tests of tangential specimens from the breech end of tubes for 3.2-inch steel breech-loading field guns.

[Length of specimen, 4.5 inches; sectional area, 0.5 of a square inch.]

Number of tube.	Number of specimens.	Elastic limit per square inch of original section.	Compression per inch under strain at elastic limit.	Ultimate strength per square inch of original section.	Number of tube.	Number of specimen.	Elastic limit per square inch of original section.	Compression per inch under strain at elastic limit.	Ultimate strength per square inch of original section.
		Pounds.	*Inch.*	*Pounds.*			*Pounds.*	*Inch.*	*Pounds.*
1	3	....	....	94, 400	14	6	47, 000	.001500	92, 600
1	6	48, 000	.001733	94, 200	15	3	50, 000	.001650	93, 800
2	3	45, 000	.001600	89, 600	16	3	49, 000	.001500	93, 000
3	3	58, 000	.001750	99, 000	16	6	48, 000	.001500	91, 200
3	6	47, 000	.001650	99, 380	16	9	47, 000	.001500	90, 420
4	3	46, 000	.001400	88, 080	17	3	48, 000	.001750	88, 800
5	3	48, 000	.001650	93, 600	18	3	46, 000	.002150	89, 400
6	3	54, 000	.001750	96, 600	19	3	52, 000	.001550	90, 900
7	3	54, 000	.001750	95, 200	20	3	50, 000	.001650	99, 220
8	3	48, 000	.001200	95, 300	21	3	49, 000	.001600	89, 980
9	3	62, 000	.001800	97, 600	22	3	36, 000	.001200	87, 600
10	3	50, 000	.001450	90, 200	22	6	43, 000	.001333	76, 020
11	3	50, 000	.001600	96, 600	23	3	....	....	96, 200
12	3	57, 000	.001800	95, 720	24	3	40, 000	.001300	87, 600
13	3	58, 000	.002150	96, 180	24	6	38, 000	.001400	81, 300
13	6	48, 000	.001600	92, 200	24	9	47, 000	.001500	84, 200
14	3	56, 000	.001700	101, 960	25	3	50, 000	.001250	91, 600

Results of tensile tests of tangential specimens from ends of jackets for 3.2-inch steel breech-loading field guns.

[Length of specimen, 2 inches: sectional area, 0.2 of a square inch.]

Number of jacket.	Breech or muzzle.	Number of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.	Specific gravity.
			Pounds.	*Inch.*	*Pounds.*	*Pr cent.*	*Pr cent.*	
1	Breech	1	52,000	.001600	99,100	20.0	40.5	7.8695
1	....do	2	50,000	.001500	95,000	16.5	24.0	....
2	....do	1	60,000	.002500	106,000	16.5	30.5	7.8656
2	....do	2	57,000	.001850	99,400	18.5	43.5	....
3*	Muzzle	1	60,000	.002400	107,300	13.0	13.2	7.8590
3*	do	2	57,000	.002500	107,250	15.0	23.9	....
3	Breech	5	51,000	.001900	99,700	20.50	43.3	....
3	....do	6	49,000	.001600	96,400	22.0	43.3	....
3	....do	7	49,000	.001800	95,250	14.50	20.5	....
3†	Muzzle	4	50,000	.001600	96,600	21.50	40.3	....
3†	....do	5	50,000	.001600	94,600	21.50	30.7	....
3†	....do	6	49,000	.001550	94,250	10.50	13.2	....
4	....do	4	50,000	.001800	94,350	21.0	40.3	....
4	....do	5	50,000	.001650	91,900	20.50	40.3	....
4	....do	6	50,000	.001650	93,350	22.50	37.1	....
4*	....do	1	50,000	.001800	104,100	10.5	13.5	7.8666
4*	....do	2	52,000	.001750	104,000	18.0	17.0	....
5‡	....do	1	56,000	.001650	100,900	19.50	37.1	7.8750
5‡	....do	2	56,000	.002050	100,000	13.50	20.5	....
New 5	Breech	4	55,000	.001850	95,800	25.0	49.1	....
New 5	....do	5	60,000	.002250	101,650	20.50	27.4	....
6	Muzzle	1	48,000	.001400	94,450	21.0	43.8	7.8593
6	....do	2	48,000	.001700	94,750	21.50	46.2	....
7§	....do	1	46,000	.001650	93,050	21.50	43.8	7.8671
7§	....do	2	45,000	.001750	90,500	23.50	30.7	....
7§	Breech	4	47,000	.001500	93,450	21.50	43.3	....
7§	....do	5	48,000	.001700	95,800	15.0	20.5	....
7§	....do	6	46,000	.002000	93,800	20.0	20.5	....
7	....do	7	49,000	.001800	101,000	19.0	34.0	....
7	....do	8	52,000	.001800	105,200	15.50	30.7	....
8§	....do	1	46,000	.001550	91,400	24.50	37.1	7.8694
8§	....do	2	45,000	.001350	94,000	17.50	27.4	....
8‡	Muzzle	4	48,000	.001750	96,100	21.50	34.0	....
8‡	....do	5	44,000	.001500	90,350	18.5	16.9	....
8‡	....do	6	47,000	.001650	93,300	18.0	27.4	....
New 8†	....do	7	52,000	.001550	105,600	18.50	34.0	....
New 8†	....do	8	53,000	.001800	108,050	10.0	13.2	....
New 8	....do	10	53,000	.002200	108,100	18.50	30.7	....
New 8	....do	11	52,000	.001900	105,100	17.0	34.0	....
New 8	....do	12	53,000	.002100	105,900	19.0	34.0	....
9§	Breech	1	50,000	.001700	98,750	17.50	37.1	7.8641
9§	....do	2	48,000	.001550	99,600	12.50	5.7	....
9‡	....do	4	49,000	.001700	94,900	23.50	30.7	....
9‡	....do	5	48,000	.001600	89,500	10.50	18.2	....
9‡	....do	6	49,000	.001800	94,100	20.0	43.8	....
New 9	....do	7	51,000	.001850	109,400	17.0	37.1	....
New 9	....do	8	52,000	.001700	105,900	17.50	30.7	....
10	....do	1	55,000	.001750	98,850	18.0	43.3	....
10	....do	2	57,000	.001950	103,800	15.50	30.7	....
11‡	....do	1	48,000	.001750	97,500	16.50	27.4	....
11‡	....do	2	47,000	.001650	96,500	12.0	18.2	....
New 11	....do	4	51,000	.001700	98,400	21.0	34.0	....
New 11	....do	5	50,000	.001750	98,800	21.0	43.3	....
12	....do	1	56,000	.002000	96,500	26.0	43.3	....
12	....do	2	53,000	.001850	90,000	28.50	51.9	....
13	....do	1	50,000	.001750	95,550	19.0	40.3	....
13	....do	2	52,000	.001700	97,550	19.0	37.1	....
14	....do	1	53,000	.001800	93,600	21.0	43.3	....
14	....do	2	54,000	.001850	95,300	22.50	40.3	....
15	Muzzle	1	53,000	.001850	101,550	21.0	37.1	....
15	....do	2	50,000	.001900	100,300	21.50	37.1	....
16	Breech	1	54,000	.001900	101,250	16.50	23.9	....
16	....do	2	56,000	.002000	99,050	22.0	43.3	....
17§	....do	1	48,000	.001750	95,600	21.0	34.0	....
17§	....do	2	48,000	.001700	96,700	21.0	40.3	....
17	Muzzle	1	52,000	.001800	102,400	18.0	40.3	....
17	....do	2	48,000	.001700	94,500	22.50	43.3	....

* Not accepted on these results; reannealed.
† Not accepted on these results; retested.
‡ Rejected.
§ Not accepted on these results; retempered and annealed.

Results of tensile tests of tangential specimens from ends of jackets for 3.2-inch steel breech-loading field guns—Continued.

Number of jacket.	Breech or muzzle.	Number of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.	Specific gravity.
			Pounds.	*Inch.*	*Pounds.*	*Pr cent.*	*Pr cent.*	
18*	Breech	1	45,000	.001500	94,450	20.50	37.1	....
18*	....do	2	46,000	.001450	96,800	20.0	37.1	....
18	Muzzle	4	49,000	.001600	98,700	15.50	23.9	....
18	....do	5	49,000	.001800	100,400	20.0	37.1	....
19	Breech	1	63,000	.001900	109,800	18.50	40.3	....
19	....do	2	58,000	.001750	99,900	21.0	46.2	....
20	Muzzle	1	52,000	.001630	88,500	24.50	46.2	....
20	....do	2	57,000	.002100	89,600	17.0	27.4	....
21*	Breech	1	53,000	.001600	88,400	18.0	20.5	....
21*	...do	2	50,000	.001550	86,750	24.0	34.0	....
21†	....do	4	46,000	.001630	95,550	22.0	43.3	....
21†	....do	5	47,000	.001630	92,550	21.50	46.2	....
New 21‡	Muzzle	7	57,000	.002050	107,900	14.0	20.5	....
New 21‡	....do	8	57,000	.001800	107,400	22.50	37.1	....
New 21	....do	10	55,000	.001800	102,450	23.50	46.2	....
New 21	....do	11	54,000	.001700	102,100	23.50	30.7	....
22	....do	1	62,000	.002000	109,050	19.50	30.7	....
22	...do	2	59,000	.001750	102,450	20.0	43.3	....
23	Breech	1	56,000	.001850	95,000	21.0	34.0	....
23	....do	2	58,000	.001950	99,850	24.0	43.3	....
24	Muzzle	1	59,000	.002000	103,550	21.50	43.3	....
24	....do	2	57,000	.002100	101,600	20.0	40.3	....
25	Breech	1	54,000	.002100	96,600	25.0	49.1	....
25	....do	2	53,000	.001850	94,000	26.0	49.1	....

* Not accepted on these results; retempered and annealed.
† Rejected.
‡ Not accepted on these results; reannealed.

Results of compression tests of tangential specimens from the ends of jackets for 3.2-inch steel breech-loading field guns.

[Length of specimen, 4.5 inches; sectional area, 0.5 of a square inch.]

Number of jacket.	Breech or muzzle.	Number of specimen.	Elastic limit per square inch of original section.	Compression per inch under strain at elastic limit.	Ultimate strength per square inch of original section.	Number of jacket.	Breech or muzzle.	Number of specimen.	Elastic limit per square inch of original section.	Compression per inch under strain at elastic limit.	Ultimate strength per square inch of original section.
			Pounds.	*Inch.*	*Pounds.*				*Pounds*	*Inch.*	*Pounds.*
1	Breech	3	48,000	.001600	95,800	14	Breech	3	46,000	.001550	92,000
2	....do	3	54,000	.001850	100,100	15	Muzzle	3	50,000	.001650	99,000
3	Muzzle	3	59,000	.001950	105,800	16	Breech	3	57,000	.002000	96,020
4	....do	3	58,000	.001650	104,000	17	....do	3	47,000	.001300	89,600
5	....do	3	54,000	.001900	99,300	17	Muzzle	6	49,000	.001567	99,920
5	Breech	6	55,000	.002100	100,000	18	Breech	3	46,000	.001550	104,400
6	Muzzle	3	50,000	.001500	95,200	18	Muzzle	6	51,000	.001867	102,640
7	do	3	48,000	.001600	96,200	19	Breech	3	54,000	.001600	99,800
7	Breech	6	45,000	.001070	92,800	20	Muzzle	3	50,000	.001467	....
8	do	3	42,000	.001390	89,000	21	Breech	3	49,000	.002050	85,600
8	Muzzle	9	53,000	.002067	104,640	21	... do	6	48,000	.001867	97,600
9	Breech	3	54,000	.002000	94,800	21	Muzzle	9	56,000	.001900	101,920
9	....do	9	51,000	.001667	100,800	21	....do	12	54,000	.002067	97,160
10	....do	3	50,000	.001800	96,200	22	....do	2	55,000	.001400	96,360
11	....do	3	43,000	.001433	91,760	23	Breech	3	55,000	.001800	95,040
11	....do	6	51,000	.001567	98,200	24	Muzzle	3	57,000	.001833	98,160
12	....do	3	55,000	.002000	91,600	25	Breech	3	56,000	.002000	94,500
13	....do	3	54,000	.001900	99,800						

Results of tensile tests of tangential specimens from trunnion hoops for 3.2-inch steel breech-loading field guns.

[Length of specimen, 2 inches; sectional area, 0.2 of a square inch.]

Number of trunnion-hoop.	No. of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.	Number of trunnion-hoop.	No. of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.
		Pounds.	*Inch.*	*Pounds.*	*P. ct.*	*P. ct.*			*Pounds.*	*Inch.*	*Pounds.*	*P. ct.*	*P. ct.*
1*	1	47,000	.001650	90,400	8.50	5.7	15	1	55,000	.001950	95,800	26.0	54.6
1*	2	48,000	.001450	90,000	9.50	5.7	15	2	54,000	.001750	95,050	25.0	46.2
1*	3	50,000	.001550	91,480	12.0	13.2	15	3	54,000	.001700	95,600	25.0	51.9
New 1	4	54,000	.001750	100,000	15.50	20.5	16†	1	50,000	.001700	96,500	14.50	16.9
New 1	5	55,000	.001950	97,900	21.0	51.9	16†	2	52,000	.001850	98,800	16.50	27.4
New 1	6	56,000	.001800	101,100	16.0	27.4	16†	3	50,000	.001750	87,900	3.50	5.7
2*	1	52,000	.001850	91,850	14.0	16.9	16	4	52,000	.001800	98,200	20.0	37.1
2*	2	54,000	.001750	87,550	19.50	30.7	16	5	52,000	.001700	99,000	22.0	37.1
2*	3	54,000	.001800	87,500	10.50	13.2	16	6	51,000	.001600	97,950	19.5	34.0
New 2	4	53,000	.00'900	95,900	15.50	43.3	17	1	52,000	.002150	99,600	20.0	37.1
New 2	5	58,000	.002200	102,100	14.50	23.9	17	2	54,000	.002000	101,000	20.0	40.3
New 2	6	55,000	.001850	98,700	20.50	49.1	17	3	51,000	.001850	98,550	18.0	37.1
3	1	52,000	.001650	98,250	19.50	27.4	18†	1	53,000	.001850	95,250	5.50	9.5
3	2	52,000	.001700	98,300	19.50	34.0	18†	2	53,000	.001850	98,900	16.0	20.5
3	3	51,000	.001650	98,100	13.50	13.2	18†	3	54,000	.001750	97,000	22.50	40.3
4	1	51,000	.001750	99,600	16.0	27.4	18*	4	47,000	.001600	88,800	23.0	34.0
4	2	51,000	.001950	99,300	18.0	30.7	18*	5	45,000	.001400	85,500	30.5	59.8
4	3	54,000	.001800	99,600	20.0	27.4	18*	6	44,000	.001400	84,200	31.0	59.8
5	1	56,000	.001900	100,960	19.0	34.0	New 18	7	50,000	.001550	95,050	20.0	37.1
5	2	56,000	.001900	100,500	18.50	34.0	New 18	8	51,000	.001650	94,900	19.50	30.7
5	3	52,000	.002000	97,800	17.50	27.4	New 18	9	49,000	.001700	94,700	19.50	34.0
6	1	53,000	.002250	97,750	21.0	40.3	19	1	55,000	.001800	105,350	14.0	16.9
6	2	53,000	.001850	95,600	22.50	37.1	19	2	56,000	.001850	106,400	18.50	23.9
6	3	52,000	.001800	98,100	24.0	40.3	19	3	54,000	.001850	103,600	17.50	16.9
7†	1	52,000	.001850	97,600	22.50	37.1	20†	1	51,000	.001750	93,400	18.50	30.7
7†	2	51,000	.001600	93,500	7.0	9.5	20†	2	51,000	.001700	98,900	5.0	5.7
7†	3	51,000	.001800	98,800	23.50	40.3	20†	3	51,000	.001600	96,500	11.50	9.5
7	4	60,000	.002100	100,000	21.0	43.3	20	4	48,000	.001500	94,000	23.50	40.3
7	5	52,000	.001700	93,900	26.0	49.1	20	5	48,000	.001600	94,050	23.50	40.3
7	6	55,000	.001750	96,400	24.50	49.1	20	6	46,000	.001350	90,500	26.0	49.1
8	1	58,000	.001900	97,500	23.0	43.3	21†	1	49,000	.001700	87,750	8.0	9.5
8	2	52,000	.001600	96,950	19.0	40.3	21†	2	48,000	.001700	86,000	10.0	9.5
8	3	52,000	.001700	97,600	22.50	43.3	21†	3	49,000	.001700	89,950	20.0	37.1
9	1	54,000	.001800	99,600	20.0	43.3	21	4	48,000	.001650	88,150	28.0	51.9
9	2	52,000	.001800	96,300	26.0	43.3	21	5	51,000	.001700	90,700	25.0	49.1
9	3	54,000	.001800	97,250	23.0	46.2	21	6	50,000	.001650	88,050	29.0	51.9
10	1	51,000	.001700	96,500	20.0	43.3	22	1	52,000	.001800	98,100	20.0	34.0
10	2	49,000	.001600	95,200	22.0	37.1	22	2	51,000	.001750	96,250	15.0	16.9
10	3	53,000	.001850	96,500	25.0	46.2	22	3	52,000	.001650	96,800	20.0	37.1
11	1	51,000	.0016 0	95,500	19.0	40.3	23	1	52,000	.001550	95,900	13.0	16.9
11	2	52,000	.001800	96,500	21.50	40.3	23	2	52,000	.001700	96,000	16.0	30.7
11	3	50,000	.001800	94,600	23.0	40.3	23	3	51,000	.001500	93,700	15.0	27.4
12	1	51,000	.001700	95,800	21.50	43.3	24†	1	52,000	.001800	94,900	23.50	51.9
12	2	51,000	.001650	97,750	22.0	40.3	24†	2	51,000	.001750	95,900	14.0	16.9
12	3	49,000	.001850	94,600	19.0	34.0	24†	3	52,000	.001800	93,000	9.0	9.5
13	1	52,000	.001700	98,600	14.0	13.2	24	4	59,000	.001900	95,100	14.0	39.5
13	2	49,000	.001650	94,750	20.50	30.7	24	5	56,000	.001950	95,800	26.0	57.2
13	3	52,000	.001750	98,100	22.50	40.3	24	6	56,000	.001900	95,200	25.0	57.2
14	1	50,000	.001700	98,050	19.0	37.1	25†	1	54,000	.001850	98,400	11.0	16.9
14	2	51,000	.001850	100,100	20.0	30.7	25†	2	52,000	.001900	96,750	16.50	23.9
14	3	51,000	.001800	98,400	15.50	27.4	25†	2	54,000	.001700	96,200	19.0	37.1
15†	1	51,000	.001650	96,250	20.0	37.1	25	4	55,000	.001800	96,950	22.50	51.9
15†	2	50,000	.001750	88,000	5.50	5.7	25	5	53,000	.001800	96,500	19.50	37.1
15†	3	49,000	.001750	94,900	21.50	37.1	25	6	55,000	.001900	98,250	13.50	30.7

* Rejected. † Not accepted on these results; retested.

Results of tensile tests of tangential specimens from the ends of breech-blocks for 3.2 inch steel breech-loading field guns.

[Length of specimen, 2 inches; sectional area, 0.2 of a square inch.]

No. of breech-block.	No. of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.	No. of breech-block.	No. of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.
		Pounds.	*Inch.*	*Pounds.*	*P. ct.*	*P. ct.*			*Pounds.*	*Inch.*	*Pounds.*	*P. ct.*	*P. ct.*
1	1	50,000	.001750	102,600	15.50	27.4	14	1	54,000	.002050	101,400	16.0	34.0
2	1	54,000	.001850	102,000	17.0	34.0	15	1	50,000	.001600	103,025	16.50	27.4
3	1	51,000	.001750	97,600	18.50	27.4	16	1	52,000	.001700	102,400	16.0	30.7
4	1	53,000	.001700	100,300	16.0	34.0	17	1	52,000	.001600	100,050	17.0	34.0
5	1	50,000	.001700	97,800	18.50	30.7	18	1	53,000	.001600	103,100	18.0	34.0
6	1	54,000	.001750	106,750	17.50	30.7	19	1	52,000	.001900	99.900	19.50	34.0
7	1	50,000	.001650	96,300	19.0	37.1	20	1	47,000	.001400	97,900	16.50	30.7
8	1	54,000	.001900	101,500	18.50	34.0	21	1	49,000	.001550	101,550	16.0	34.0
9	1	55,000	.001950	10,400	18.0	30.7	22	1	50,000	.001700	99,350	18.0	34.0
10	1	49,000	.001600	100,600	15.50	27.4	23	1	47,000	.001650	99,150	15.50	30.7
11	1	55,000	.002150	106,700	17.50	30.7	24	1	49,000	.001700	98,700	20.50	30.7
12	1	52,000	.001750	99,100	21.50	34.0	25	1	44,000	.001150	95,600	19.0	30.7
13	1	55,000	.001700	101,500	16.0	30.7	25	3	60,000	.002000	99,950	22.50	43.3

Results of compression tests of tangential specimens from the ends of breech-blocks for 3.2 inch steel breech-loading field guns.

[Length of specimen, 4.5 inches; sectional area, 0.5 of a square inch.]

No. of breech-block.	No. of specimen.	Elastic limit per square inch of original section.	Compression per inch under strain at elastic limit.	Ultimate strength per square inch of original section.	No. of breech-block.	No. of specimen.	Elastic limit per square inch of original section.	Compression per inch under strain at elastic limit.	Ultimate strength per square inch of original section.
		Pounds.	*Inch.*	*Pounds.*			*Pounds.*	*Inch.*	*Pounds.*
1	2	57,000	.002000	106,200	14	2	57,000	.001600	111,800
2	2	54,000	.001800	108,400	15	2	52,000	.001650	113,800
3	2	52,000	.001600	104,600	16	2	53,000	.001500	106,400
4	2	53,000	.001600	107,200	17	2	50,000	.001750	105,000
5	2	52,000	.001800	108,200	18	2	60,000	.001800	110,800
6	2	57,000	.001500	113,200	19	2	54,000	.001750	105,000
7	2	52,009	.001350	105,400	20	2	45,000	.001300	101.400
8	2	54,000	.001750	109,200	21	2	50,000	.001700	105,000
9	2	55,000	.001750	110,800	22	2	53,000	.001500	107,000
10	2	49,000	.001750	110,800	23	2	47,000	.001050	103,600
11	2	52,000	.001500	112,200	24	2	50,000	.001650	105,400
12	2	51,000	.001600	107,200	25	2	47,000	.000850	103,000
13	2	52,000	.001600	113,400	25	4	61,000	.001950	106,320

Results of tensile tests of tangential specimens from sleeves for 3.2-inch steel breech-loading field guns.

[Length of specimen, 2 inches. Sectional area, 0.2 of a square inch.]

No. of sleeve.	No. of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.	Specific gravity.
		Pounds.	*Inch.*	*Pounds.*	*Per cent.*	*Per cent.*	
1	1	61,000	.002100	109,500	20.50	40.3	7.8621
5	1	56,000	.001950	106,500	15.0	30.7	7.8627
10	1	55,000	.001800	105,000	18.50	34.0	7.8636
15	1	59,000	.002000	110,000	15.50	30.7	7.8655
20	2	54,000	.001900	97,000	25.0	54.6	
21	1	54,000	.001700	100,000	19.0	40.3	
25	1	54,000	.001700	104,450	17.0	34.0	

Results of tensile tests of tangential specimens from base rings for 3.2-inch steel breech-loading field guns.

[Length of specimen, 2 inches. Sectionel area, 0.2 of a square inch.]

No. of base ring.	No. of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.	Specific gravity.
		Pounds.	*Inch.*	*Pounds.*	*Per cent.*	*Per cent.*	
1	1	52,000	.001850	103,550	19.0	30.7	7.8678
5	1	57.000	.001900	110,550	15.0	23.9	7.8667
10	1	53,000	.001750	102,900	17.0	34.0	7.8646
15	1	57,000	.001900	109,000	19.50	30.7	7.8623
20	1	59,000	.002150	107,750	16.50	34.0	7.8616
25	1	47,000	.001500	102,900	19.0	30.7	7.8672

Results of compression tests of tangential specimens from base rings for 3.2-inch steel breech-loading field guns.

[Length of specimen, 4.5 inches. Sectional area, 0.5 of a sqaro inch.]

No. of base ring.	No. of specimen.	Elastic limit per square inch of original section.	Compression per inch under strain at elastic limit.	Ultimate strength per square inch of original section.
		Pounds.	*Inch.*	*Pounds.*
1	2	49,000	.001400	101,100
5	2	57,000	.001800	108,480
10	2	59,000	.001800	105,800
15	2	59,000	.001800	106,840
20	2	51,000	.001600	100,960
25	2	50,000	.001500	95,900

Results of compression tests of longitudinal specimens from the ends of obturator stems for 3.2-inch steel breech-loading field guns.

[Length of specimen, 4.5 inches. Sectional area, 0.5 of a square inch.]

No. of obturator stem.	No. of specimen.	Elastic limit per square inch of original section.	Compression per inch under strain at elastic limit.	Tensile strength per square inch of original section.
		Pounds.	*Inch.*	*Pounds.*
1	1	60,000	.001800	109,400
5	1	60,000	.001750	110,900
10	1	73,000	.002400	110,760
15	1	57,000	.001800	104,480
20	1	63,000	.002100	113,160
25	1	65,000	.002300	112,160

TUBE, JACKET, AND TRUNNION HOOP FOR AN 8-INCH STEEL BREECH-LOADING RIFLE.

The rough finished dimensions of these forgings, and the required physical qualities of the metal, were given in report for the fiscal year ending June 30, 1885, and at that date the tube and jacket had been forged.

No work had been done on the trunnion-hoop, the intention being to postpone the manufacture of this piece until the 8-inch experimental trunnion-hoop had been thoroughly tested, so that if weakness in any part of the experimental trunnion-hoop was shown, an attempt might be made by proper changes in manufacture or treatment to make the trunnion-hoop for the gun of uniform strength.

Work on the tube progressed very satisfactorily for the first venture in the manufacture of so large a piece. The results of test of the first sets of specimens taken from the ends of the forging, which were as follows:

Results of tensile tests of specimens from ends of tube for 8 inch steel breech-loading rifle.

From—	Number.	Length.	Sectional area.	How taken.	Position of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
		Inch.				*Lbs.*	*Inch.*	*Lbs.*	*Pr ct.*	*Lbs.*		
Breech..	1	3	0.25 of a square inch.	Tangentially...	Inside...	40,000	.001300	79,760	22.67	47.2	......	......
Do.....	2	3		... do...........	Outside.	44,000	.001467	83,440	22.67	49.7	......	......
Do.....	3	3		....do...... .	Middle .	43,000	.001533	83,400	23.0	49.7	......	......
Do.....	9	2	0.2 of a square inch.	Longitudinally	Outside.	49,000	.001650	89,500	26.50	54.6	......	......
Do.....	10	2		... do.....	Inside...	46,000	.001450	84,400	27.0	59.8	......	......
Muzzle..	1	3	0.25 of a square inch.	Tangentially...	...do.....	56,000	.001900	95,920	16.67	30.6	7.8561	19.81
Do.....	2	3		....do...........	Outside.	48,000	.001567	89,700	23.33	47.2	......	......
Do...	3	3		....do....... ..	Middle..	47,000	.001667	90,560	19.0	27.6	......	......

Results of compression tests of specimens from ends of tube for 8-inch steel breech-loading rifle.

From—	Number.	Length.	Sectional area.	How taken.	Position of specimen.	Elastic limit per square inch of original section.	Compression per inch under strain at elastic limit.	Ultimate strength per square inch of original section.
		Inch.				*Pounds.*	*Inch.*	*Pounds.*
Breech...	4	5	0.5 of a square inch.	Tangentially......	Inside	39,000	.001400	70,360
Do.....	5	5		....do	Outside...	47,000	.001500	81,300
Do.....	6	5		....do	Middle....	40,000	.001500	72,840
Do.....	7	4		Radially	....	44,000	.001450	93,700
Do.....	8	4		... do	....	42,000	.001300	89,880
Muzzle...	4	5		Tangentially......	Inside	56 000	.001767	83,560
Do.....	5	5		... do	Outside...	52,000	.001767	87,300
Do	6	5		....do	Middle....	51,000	.001633	83,800
Do.....	7	3		Radially	....	51,000	.001700	....
Do.....	8	3		....do	....	49,000	.001700	....

Showed the breech to be softer and the muzzle end somewhat harder than was required, but after retreatment additional specimens cut from the ends of the forging showed the following very satisfactory results, which are believed to be as uniform and of as high a character as can be expected, and are certainly not excelled by any results of test of similar forgings which have come to the knowledge of this office:

Results of tensile tests of additional specimens from ends of tube for 8-inch steel breech-loading rifle.

From—	Number.	Length.	Sectional area.	How taken.	Position of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.
		Inch.				*Pounds.*	*Inch.*	*Pounds.*	*Pr. ct.*	*Pr. ct.*
Breech..	11	3	0.25 of a square inch.	Tangentially....	Inside ..	49,000	.001700	86,840	23.33	49.7
Do...	12	3		....do	Outside.	51,000	.001767	90,400	20.0	52.2
Do....	13	3		....do	Middle..	46,000	.001467	86,200	21.0	52.2
Muzzle .	9	3		....do	Inside ..	53,000	.001733	94,320	17.0	21.4
Do....	10	3		....do	Outside.	52,000	.001800	94,080	19.67	54.6
Do....	11	3		....do	Middle..	50,000	.001733	91,600	21.33	41.9

Results of compression tests of additional specimens from ends of tube for 8-inch steel breech-loading rifle.

From—	Number.	Length.	Sectional area.	How taken.	Position of specimen.	Elastic limit per square inch of original section.	Compression per inch under strain at elastic limit.	Ultimate strength per square inch of original section.
		Inch.				*Pounds.*	*Inch.*	*Pounds.*
Breech ..	14	5	0.5 of a square inch.	Tangentially....	Inside ..	49,000	.001700	85,760
Do.....	15	5	0.5 of a square inch.	....do	Outside.	50,000	.001767	93,400
Do.....	16	4	0.5 of a square inch.	Radially	....	47,000	.93400	97,040
Muzzle ..	12	5	0.5 of a square inch.	Tangentially....	Inside ..	57,000	.001900	94,600
Do.....	13	5	0.5 of a square inch.	....do	Outside.	53,000	.001733	91,360
Do.....	14	3	0.5 of a square inch.	Radially	....	53,000	.002050	112,250

During treatment the tube was somewhat warped, but not sufficiently to prevent its being finished to the dimensions required.

It was noted in report for the fiscal year ending June 30, 1885, that the preliminary tests from the jacket had not shown very satisfactory results, but notwithstanding this fact the company had this forging rough turned and bored, and during the month of December last treated it. Being unable to obtain any satisfactory test of the metal after treatment, they did not submit the piece for test by the Department, and proceeded to forge another jacket. Preliminary specimens cut from this forging showed defects in the metal which necessitated its condemnation.

At a later date partial forging of another ingot showed it to be unfit to have the forging work continued. All the large ingots, considered at that time suitable for this piece, having then been used, other ingots were cast, and in March last the forging of another ingot was satisfactorily completed. Very exhaustive test of this forging, and of treated pieces cut from it, extending over about three months, seemed to show that the steel was harder than was desirable. No perfectly satisfactory results of test or result filling the contract requirements could be obtained, and this forging was condemned by the company.

With the experience and knowledge that has been gained by these several failures the company are preparing to make another forging within a week or two, and hope to be successful. Without expressing too confidently the opinion that they will be so, it is believed at this office that everything points toward success.*

These repeated failures to obtain satisfactory results in an 8-inch jacket-forging are unfortunate, but explainable by the fact that this new and heavy work presents difficulties to the manufacturer not previously met, and with this company requires the very fullest application of the existing plant, even though the plant has been added to within the past two years. Nowhere else in this country could this work be done at all.

* Since writing the above this jacket-forging has been made, the preliminary tests and the tests of treated pieces are very good, or certainly far better than anything previously obtained, and the work of rough-boring and turning the forging will be proceeded with at once.

The specifications of the Department's contracts for these forgings, as in all contracts for gun material, are such, that practically perfect metal, work, and treatment are required to enable the manufacturer to successfully fill them. They are not, however, it is believed, in any case more severe than the importance of the work demands, nor so severe but that, with the great care which should be used in manufacture, they can be fairly if not fully met. So far as these 8-inch forgings are concerned, it will be noted from the summaries of test that the contract specifications have been very satisfactorily met as to the tube and trunnion-hoop, and it is believed that as to the jacket they can also be met.

The experimental 8-inch trunnion-hoop having shown satisfactory results of test, the trunnion-hoop for 8-inch rifle required under this contract was made and treated in a similar manner.

Tests of specimens cut from the ends of the hoop showed the following very satisfactory results:

Results of tensile tests of tangential specimens from ends of trunnion-hoop for 8-inch steel breech-loading rifle.

[Length of specimen, 6 inches; sectional area, 0.25 of a square inch.]

Number of specimen.	Position of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.	Remarks.
		Pounds.	*Inch.*	*Pounds.*	*Per cent.*	*Per cent.*	
1	Middle	54,000	.001700	105,640	14.67	41.9	From one end of the hoop.
2	..do	54,000	.001750	105,120	12.83	33.5	
3	..do	60,000	.001967	110,000	13.67	41.9	
4	..do	60,000	.001950	110,080	14.17	39.2	
5	Outside	58,000	.001833	105,920	15.17	30.2	From the other end of the hoop.
6	Middle	54,000	.001783	105,200	12.83	24.6	
7	Inside	66,000	.002233	112,000	13.0	44.6	
8	Middle	55,000	.001883	107,800	12.83	18.3	

EXPERIMENTAL TRUNNION-HOOP FOR AN 8-INCH STEEL BREECH-LOADING RIFLE.

The manufacture of a forged 8-inch trunnion-hoop in this country was, at the time the Midvale Steel Company contracted for the manufacture of the tube, jacket, and trunnion-hoop forgings required for an 8-inch steel breech-loading rifle, more a matter of experiment than the manufacture of the tube and jacket. No forged trunnion-hoops had been made.

Tube and jacket forgings of smaller size had been successfully produced. The trunnion-hoops manufactured had been cast-steel castings, the physical qualities of which were not so good as desired by the Department, and the manufacturers would not undertake to furnish a casting of the qualities required. It is true an attempt was made by the Midvale Steel Company some time before to forge trunnion-hoops, but as the requirement that the hoops should be forged was not insisted on, high physical qualities were not required, and the attempt was a failure. Nothing further in this line was done until the Department pushed the matter.

Little or no information in regard to the qualities of trunnion-hoops was at hand, so in order to obtain absolutely the qualities of a forged trunnion-hoop throughout the mass, to determine consequently the

average qualities, what falling off in elastic strength there was, if any, toward the middle of the thickness and at the base of the trunnions and incidentally to give the Midvale Steel Company some little experience with that forging (the trunnion-hoop), in respect to the manufacture of which they had more fear as to their ability than either the tube or jacket, you were pleased, in the month of July, 1885, after very full discussion, and after a proposition to manufacture both a forged and cast experimental trunnion-hoop had been decided in the negative, to direct the manufacture of a forged experimental trunnion-hoop of the size required for an 8-inch breech-loading steel rifle, to be left rough as it came from the hammer, except that it was to be bored to within one-eighth inch on a side of the finished interior diameter, and, when oil tempered, to have as little surplus metal as possible, especially in the vicinity of the trunnions and rim-bases. An extra length of 2 inches at each end was allowed for taking test specimens, to determine the acceptance or non-acceptance of the hoop.

Very low physical qualities were demanded, viz: In specimens 6 inches long between shoulders and 0.564 of an inch in diameter—

Elastic limit, 45,000 pounds per square inch;

Tensile strength, 95,000 pounds per square inch;

Elongation after rupture, 15 per cent.

The results of the test of no one specimen to be below—

Elastic limit, 42,000 pounds per square inch;

Tensile strength, 88,000 pounds per square inch;

Elongation after rupture 12 per cent.;

and it was hoped and expected that much higher qualities would be obtained.

Though some difficulty was experienced in forging the hoop, the manufacture throughout was very satisfactory, and much less difficulty was met than had been anticipated. It was made from an ingot weighing about 13,000 pounds, was frequently retreated, and when the operation of forging was completed varied considerably on the exterior from the required dimensions, so much, in fact, that before treatment metal was cut from it in the vicinity of the rim-bases. After this operation and the rough-boring, its dimensions approximated quite closely to the rough-finished dimensions required.

The forging was annealed at a high heat before oil-tempering, and after that operation was again annealed at a lower temperature.

The results of the test of four specimens from each end of the hoop were as follows:

[Length of specimen, 6 inches; sectional area, 0.25 of a square inch.]

Number of specimen.	Position of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.	Remarks.
		Pounds.	*Inch.*	*Pounds.*	*Per cent.*	*Per cent.*	
1	Middle	50,000	.001617	90,440	19.17	49.7	From one end of hoop.
2	...do...	55,000	.001817	93,600	17.67	36.4	
3	...do...	54,000	.001800	89,600	22.17	54.6	
4	...do...	57,000	.001950	93,920	18.	49.7	
5	...do...	46,000	.001583	87,000	20.33	52.2	From other end of hoop.
6	...do...	47,000	.001467	89,000	17.50	36.4	
7	...do...	43,000	.001433	87,400	19.83	47.2	
8	...do...	46,000	.001483	88,960	14.50	47.2	

On acceptance the hoop was shipped to Lieut. R. Birnie, jr., at the works of the West Point Foundry Association, at Cold Spring, N. Y., where it was to be cut up and thoroughly tested, both by further machine tests and by shrinkage tests.

FORGINGS FOR THE PARTS OF A FIVE-INCH STEEL BREECH-LOADING RIFLE.

These parts consisted of tube, jacket, sleeve, base-ring, key-ring, breech-block, obturator-stem, lever-handle, nut, carrier-ring, and trunnion-hoop, of the following rough finished dimensions:

Nature of piece.	Interior diameter.	Exterior diameter.	Length.	Remarks.
	Inches.	*Inches.*	*Inches.*	
Tube	4.6	9.8	138.25	
Jacket	8.6	15.4	59.55	
Sleeve	8.6	11.4 12.9	16.45	
Base-ring	5.75	10.3	5.75	
Key-ring	8.3	11.4	5.25	
Breech-block	0.75	7.1	9.6	With projection.
Obturator-stem		6.1 2.2	2.0 9.2	
Lever-handle		2.0	14.0	
Nut		2.0	1.25	
Carrier-ring	6.45	10.5	1.75	With projection.
Trunnion-hoop	10.6	14.8	11.18	With rim-bases and trunnions.

To be forgings of open-hearth steel, oil-tempered, and afterward annealed, and to have the following physical qualities:

Tube	Elastic limit, 42,000 pounds per square inch. Tensile strength, 88,000 pounds per square inch. Elongation after rupture, 20 per cent.	The results of the test of no one specimen to be below—	Elastic limit, 36,000 pounds per square inch. Tensile strength, 80,000 pounds per square inch. Elongation after rupture, 17 per cent.
Jacket, sleeve, breech-block, base-ring, and other small forgings—	Elastic limit, 50,000 pounds per square inch. Tensile strength, 95,000 pounds per square inch. Elongation after rupture, 18 per cent.	The results of the test of no one specimen to be below—	Elastic limit, 46,000 pounds per square inch. Tensile strength, 88,000 pounds per square inch. Elongation after rupture, 15 per cent.
Trunnion-hoop	Elastic limit, 48,000 pounds per square inch. Tensile strength, 95,000 pounds per square inch. Elongation after rupture, 15 per cent.	The results of the test of no one specimen to be below—	Elastic limit, 43,000 pounds per square inch. Tensile strength, 85,000 pounds per square inch. Elongation after rupture, 12 per cent.

The forgings for the parts of this rifle were similar in form to those for the parts of 3.2-inch steel field gun, but larger in size.

The manufacture of all the parts except the jacket proceeded rapidly and satisfactorily, and they were finished and accepted within five months of the date of the contract.

The company have not yet, however, produced a satisfactory jacket-forging. The first one forged in November last was finally rejected by the Department in March, on account of unsatisfactory results of the test of specimens taken from one end. Since that time three other jacket-forgings have been made by the company, tested and experimented with, and finally condemned without being presented to the Department for test; and as soon as a satisfactory ingot has been cast a fifth jacket-forging will be made.

This great delay in furnishing this one forging prevents completion of the rifle. It is surprising that there should have been so many failures, for the company has successfully produced quite a number of jackets for 5-inch and 6-inch guns of larger size than the one required, and the physical qualities demanded are not particularly high. The failures since the first one, which was due to imperfect material, can only be explained by the fact that the metal used was too hard.

The physical qualities of the forgings accepted are given below:

Results of tensile tests of tangential specimens from forgings for 5-inch steel breech-loading rifle.

[Length of specimen, 2 inches; sectional area, 0.2 of a square inch.]

Nature of piece tested.	End.	Number of specimen.	Position of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.
				Pounds.	*Inch.*	*Pounds.*	*Per cent.*	*Per cent.*
Tube	Breech	1	Middle	42,000	.001400	79,000	29.50	51.9
....Do	....do	2	....do	42,000	.001650	80,050	26.50	54.6
....Do	Muzzle	1	....do	42,000	.001600	83,050	20.50	34.0
....Do	..do	2	....do	42,000	.001350	82,850	24.50	46.2
Trunnion-hoop		1	Inside	56,000	.001850	99,500	25.0	51.9
....Do		2	Middle	55,000	.001900	99,100	25.0	51.9
....Do		3	....do	56,000	.001750	100,000	22.50	40.8
Sleeve		1	....do	51,000	.001850	98,900	24.50	46.2
....Do		2	....do	55,000	.001850	103,950	23.0	43.8
Base-ring		1	....do	58,000	.002200	107,000	19.50	34.0
Breech-block		1	....do	56,000	.001900	102,500	20.50	34.0

Results of compression tests of specimens from forgings for 5-inch steel breech-loading rifle.

[Length of specimen 4.5 inches; sectional area, 0.5 of a square inch.]

Nature of piece tested.	Number of specimen.	How taken.	Position of specimen.	Elastic limit per square inch of original section.	Compression per inch under strain at elastic limit.	Ultimate strength per square inch of original section.
				Pounds.	*Inch.*	*Pounds.*
Tube	3	Tangentially	Middle	45,000	.001467	80,760
Base-ring	2	....do	....do	57,000	.001900	104,800
Breech-block	2	....do	....do	55,000	.001723	102,100
Obturator-stem	1	Longitudinally		59,000	.001667	101,600

ONE HOOP FOR TEN-INCH CAST-IRON WIRE-WOUND RIFLE.

This hoop was manufactured in the usual manner without incident of interest.

The rough-finished dimensions required were:

	Inches.
Interior diameter	$28\frac{1}{4}$
Exterior diameter	$36\frac{1}{4}$
Length	$10\frac{1}{4}$

It was accepted on the results of test of specimens showing the following physical qualities:

[Length of specimens, 6 inches; sectional area, 0.25 of a square inch.]

Number of specimen.	Position of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.
		Pounds.	*Inch.*	*Pounds.*	*Per cent.*	*Per cent.*
1	Inside	56,000	.001883	106,720	13.67	36.4
2	Middle	57,000	.001917	110,840	12.50	30.6
3	Outside	59,000	.001950	114,000	12.0	27.6
4	Middle	56,000	.001900	110,400	13.33	30.6

FIVE FORGED HOOPS FOR A 10-INCH STEEL BREECH-LOADING RIFLE.

These hoops, for the chase of a 10-inch steel breech-loading rifle, were required of the following rough-finished dimensions:

Number of hoops.	Mark.	Interior diameter.	Exterior diameter.	Length.
		Inches.	*Inches.*	*Inches.*
1....................	C_4 ...	16¼	22⅜ at one end tapering to 21⅝ at the other end.	31⅛
1....................	C_5	15½	21⅜ at one end tapering to 20⅝ at the other end.	31⅛
1....................	C_6	14¾	20⅜ at one end tapering to 19⅝ at the other end.	30⅛
1....................	C_7	14.0	19⅜ at one end tapering to 18⅝ at the other end.	30⅛
1....................	C_8	14.0	18⅜ at one end tapering to 17⅝ at the other end.	30⅛

and to have the usual physical qualities required by the Department in specimens, 6 inches in length between shoulders, and 0.564 of an inch in diameter, taken from hoops, viz:

Elastic limit, over 55,000 pounds per square inch.

Tensile strength, over 100,000 pounds per square inch.

Elongation after rupture, over 12 per cent.

They were of such length that it was deemed advisable to require that they be tested at both ends. Some difficulty has been experienced by the company in obtaining the required physical qualities, and retreatment has been resorted to very frequently. Two of the hoops have been accepted as to physical qualities, two others are submitted for test by the Department and have had specimens cut from them, while the fifth is still under treatment.

In deciding from their own tests of these hoops whether or not to submit them for test by the Department, the company have felt the need of a reliable testing-machine; the Fairbanks machine which was erected at these works in the winter of 1884–5 not having yet been put into use, the company have still to depend upon their old machine. This want has delayed the work somewhat.

The results obtained from the hoops tested are as follows:

Results of tensile tests of tangential specimens from hoops for 10-inch steel breech-loading rifle.

[Length of specimen, 6-inches; sectional area, 0.25 of a square inch.]

Mark of hoop.	End of hoop.	Number of specimens.	Position of specimens.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
				Pounds.	*Inches.*	*Pounds.*	*Per cent.*	*Per cent.*		
C_5	Breech	4	Inside	65,000	.002083	116,080	10.33	30.6	....	......
C_5	do	5	Outside	67,000	.002217	110,760	15.33	41.9	....	......
C_5	do	6	Middle	70,000	.002300	114,480	13.33	33.5	7.8507	24.98
C_5	Muzzle	4	Inside	66,000	.002183	107,240	12.0	36.4	....	......
C_5	do	5	Outside	68,000	.002183	112,080	12.83	39.2	....	......
C_5	do	6	Middle	66,000	.002183	108,560	14.50	41.9	....	......
C_8†	Breech	1	Inside	57,000	.001950	109,060	11.33	33.5	....	......
C_8†	do	2	Outside	54,000	.001800	105,440	13.0	36.4	....	......
C_8†	do	3	Middle	54,000	.001817	108,240	12.0	21.4	....	......
C_8†	Muzzle	1	Inside	55,000	.001867	106,720	15.0	33.5	....	......
C_8†	do	2	Outside	53,000	.001800	105,240	13.40	33.5	....	......
C_8†	do	3	Middle	53,000	.001817	106,480	13.0	30.6	....	......
C_8	Breech	4	Inside	62,000	.002000	108,640	13.33	30.6	....	......
C_8	do	5	Outside	61,000	.002017	103,520	16.0	33.5	....	......
C_8	do	6	Middle	59,000	.004900	102,480	14.0	27.6	7.8466	23.17
C_8	Muzzle	4	Inside	61,000	.002017	107,280	11.17	27.6	....	......
C_8	do	5	Outside	60,000	.001967	109,480	14.67	30.6	....	......
C_8	do	6	Middle	61,000	.002067	110.880	14.50	27.6	7.8441	25.13

* Second C^5 hoop made. † Not accepted on these results; retempered and annealed.

ONE HUNDRED AND FOUR ROLLED STEEL BILLETS.

These billets for steel wire to be used in gun construction are required to be 2 inches square and to weigh about 80 pounds each.

From the bottom of each ingot used at least 5 per cent. of the total weight must be cut, and only the lower half of the remainder is to be used in the manufacture.

Two rolled billets from each ingot are to be tested; from each of these two longitudinal and two transverse specimens are to be taken, the longitudinal specimens being 2 inches long between shoulders and 0.505 of an inch in diameter; the transverse specimens being 1.3 inches between shoulders, and 0.3 of an inch in diameter.

The physical qualities required as a minimum are—

For the longitudinal specimens:
- Tensile strength, 65,000 pounds per square inch.
- Elongation after rupture, 30 per cent.
- Contraction of area, 60 per cent.

For the transverse specimens:
- Tensile strength, 65,000 pounds per square inch.
- Elongation after rupture, 14 per cent.
- Contraction of area, 20 per cent.

Though this contract was executed about four months ago, the company have as yet produced no satisfactory billets. Several heats of metal have been cast for the purpose, but none of the billets rolled from them have shown the required physical qualities.

Further attempt to fill the contract is being made by the company.

BREECH-MECHANISM FORGINGS FOR AN 8-INCH AND A 10-INCH STEEL BREECH-LOADING RIFLE AND A 12-INCH BREECH-LOADING RIFLED MORTAR.

The rough-finished dimensions of these forgings are as follows:

Nature of piece.	Interior diameter.	Exterior diameter.	Length.	Remarks.
For 8-inch steel breech-loading rifle:	*Inches.*	*Inches.*	*Inches.*	
Breech block	2.25	11.25	22.25	With projection.
Spindle		{ 2.75 / 10.0 }	28.0	
Breech-block carrier	10.0	16.3	5.5	With projection.
Lever handle			25.1	
Hinge pin		2.25	21.0	
Gas-check ring	2.5	10.1	2.5	
Breech-bushing ring	10.0	16.1	16.0	
For 10-inch steel breech-loading rifle:				
Breech block	3.0	14.75	18.0	With projection.
Spindle		{ 3.5 / 12.5 }	24.0	
Face plate	6.5	14.75	2.25	With arm 10″.75 long by 4 by 3″.15.
Gas-check ring	3.5	12.75	2.75	
Hinge pin		2.25	18.0	
Bar for securing pins		3.5	18.0	
For 12-inch breech-loading rifled mortars:				
Breech block	3.0	15.25	18.0	
Spindle		{ 3.5 / 12.75 }	23.0	
Face plate	6.5	16.5	2.25	With arm 12″.1 long by 4 by 3″.25.
Gas-check ring	3.5	13.0	2.75	
Hinge pin		2.25	18.0	

The physical qualities of the metal to be as follows:

For the breech block, gas-check rings, and spindles:

Tangential specimens, 3 inches in length between shoulders and 0.564 of an inch in diameter.

Elastic limit, not less than 51,500 pounds per square inch.

Tensile strength, not less than 100,000 pounds per square inch.

Elongation after rupture, not less than 15 per cent.

For the bushing rings:

Tangential specimens, 6 inches in length between shoulders and 0.564 of an inch in diameter.

Elastic limit, not less than 55,000 pounds per square inch.

Tensile strength, not less than 100,000 pounds per square inch.

Elongation after rupture, not less than 12 per cent.

Longitudinal specimens, 2 inches in length between shoulders and 0.505 of an inch in diameter.

Elastic limit, not less 55,000 pounds per square inch.

Tensile strength, not less than 100,000 per square inch.

Elongation after rupture, not less than 18 per cent.

The results of the test of no one specimen to be below the figures given above.

For the face plates, block carrier, lever and hinge pins:

Specimens, 3 inches in length between shoulders and 0.564 of an inch in diameter.

Elastic limit, not less than 49,000 pounds per square inch.

Tensile strength, not less than 90,000 pounds per square inch.

Elongation after rupture, not less than 15 per cent.

The results of the test of no one specimen to be below the figures given above.

For the forged bar for securing pins:

Specimens, 2 inches in length between shoulders and 0.505 of an inch in diameter.

Elastic limit, not less than 55,000 pounds per square inch.

Tensile strength, not less than 100,000 pounds per square inch.

Elongation after rupture, not less than 18 per cent.

The results of the test of no one specimen to be below the figures given above.

In all cases the forgings were required to be made of sufficient extra length over the specified to allow the contractors to furnish the required test specimens.

All these parts, except the breech blocks and spindles, have been forged, oil-tempered, and annealed, and the specimens for test are being cut from them.

TWELVE ROLLED-STEEL HOOPS AND ONE HAMMERED-STEEL TRUNNION HOOP FOR A 12-INCH BREECH-LOADING RIFLED MORTAR.

The rough-finished dimensions of the rolled hoops are as follows:

Number of hoops.	Mark.	Interior diameter.	Exterior diameter.	Length.
		Inches.	*Inches.*	*Inches.*
1	B_1.	36	41⅜	8¼
4	B_3, B_4, B_5, B_6.	36	42	9¾
1	A_1.	31¼	37⅛	12¼
1	A_2.	31¼	36⅛	12¼
4	A_3, A_4, A_5, A_6.	31¼	36⅛	9⅞
1	A^7.	31¼	36⅛	10⅜

And of the trunnion hoop:

Interior diameter, 36 inches; exterior diameter, 43 inches; length, 14.25 inches, with rim-bases and trunnions.

The physical qualities required are—

For the rolled hoops:

Elastic limit, not less than 55,000 pounds yer square inch.
Tensile strength, not less than 100,000 pounds per square inch.
Elongation after rupture, not less than 12 per cent.

The results of the test of no one specimen to be below the above figures.

For the trunnion hoop:

Elastic limit, not less than 49,000 pounds per square inch.
Tensile strength, not less than 95,000 pounds per square inch.
Elongation after rupture, not less than 12 per cent.

The results of the test of no one specimen to be below the above figures, and all are to be made of sufficient extra length over that specified to allow the contractors to furnish the required test specimens 6 inches in length between shoulders and 0.564 of an inch in diameter, of which four are to be taken from each rolled hoop, except hoops A_1, A_2 and A_7, and four from each end of the forged trunnion hoop.

The billets for the rolled hoops have all been cut from the ingots, and and are ready to roll.

The manufacture of a forged trunnion hoop of the size required was such a step in advance of the manufacture of the 8-inch forged trunnion hoops previously referred to in this report, that some hesitancy was felt in undertaking the work under penalty, as it seemed quite possible that the existing plant would be insufficient for the work, and hence you were pleased to insert in the contract the proviso that if, after experiment, the contractors found themselves unable to make the forged trunnion hoop, a steel casting for the trunnion hoop, tempered and annealed, of such physical qualities, and at such reduction in price as should be satisfactory, would be accepted in lieu of the forged hoop.

It is gratifying to note that the hoop has been very successfully forged, and was in much better shape after that operation than either of the 8 inch trunnion hoops previously made.

Tests of the metal so far as made show the forging to be in satisfactory condition.

The manufacture of this trunnion hoop, at the earnest solicitation of, and under contract with the Department, is but one more instance of the help and encouragement which the Department has been to the steel manufacturers of the country in ascertaining their ability and capacity to make gun forgings and in pushing that capacity to its limit.

APPENDIX 24.

REPORT SHOWING THE NATURE AND PROGRESS OF THE WORK DONE FOR THE ORDNANCE DEPARTMENT, UNITED STATES ARMY, BY THE CAMBRIA IRON COMPANY DURING THE FISCAL YEAR ENDING JUNE 30, 1886.

BY LIEUT. F. E. HOBBS, ORDNANCE DEPARTMENT.

CAMBRIA IRON AND STEEL WORKS,
Johnstown, Pa., July 30, 1886.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.:

SIR: Complying with your instructions I have the honor to submit the following report, showing the nature and progress of the work done for the Ordnance Department by the Cambria Iron Company during the fiscal year ending June 30, 1886.

During the time specified the Cambria Iron Company have been actively engaged in work on the forged hoops for a 10-inch steel breech-loading rifle, contract for furnishing them having been awarded the company as the lowest bidder in September last, and have also done some work towards furnishing a set of forgings for a 7-inch steel breech-loading howitzer.

FORGED HOOPS FOR A 10-INCH STEEL BREECH-LOADING RIFLE.

The rough-finished dimensions of these hoops are as follows, viz:

Number of hoops.	Mark.	Exterior diameter.	Interior diameter.	Length.
		Inches.	*Inches.*	*Inches.*
4	B_2, B_3, B_4, B_5.	39¾	33.0	19¼
1	B_6	39¾	33.0	22¼
1	B_7	39¾	33.0	6¼
1	A_1	37⅛	27¾	22¾
2	A_2, A_3	33⅝	27¾	21¼
3	A_4, A_5, A_6	33⅝	27¾	18⅜
1	A_7	33⅝	27¾	22¼
1	D_1	30¾	22¾	21¼
1	D_2	30⅛	22¾	20⅛
1	D_3	28⅞	21¾	21.0
1	D_4	27⅝	21¾	22.0
1	C_1	25¼	17⅝	21⅜
1	C_2	23¼	17⅝	21¼
1	C_3	22¼	17¼	20¼

to be of open-hearth steel of American production, to be oil-tempered and afterwards annealed, and to show the usual physical qualities for

hoops as determined by the test of tangential specimens 6 inches long between shoulders and 0.564 of an inch in diameter, viz:

- Elastic limit, over 55,000 pounds per square inch.
- Tensile strength, over 100,000 pounds per square inch.
- Elongation after rupture, over 12 per centum.

each of the hoops to be forged of sufficient extra length over that required to allow the manufacturer to furnish the test specimens required.

The work on these hoops being the first of the kind ever undertaken by this company, they were compelled to make changes in and additions to their tools and plant, to experiment considerably in the working and treatment of metal suitable for the purpose, and to educate and organize a force of employés to do the work properly after the way to do it had been determined.

All this, added to the fact that the hoops are of greater length and weight than any heretofore made in this country, and that the specifications as to physical qualities are severe, has tended to delay the completion of the contract, though the manufacturers have been lavish in expenditure of money and have displayed great energy and perseverance in overcoming the troubles or obstacles that arose at the commencement of the work.

Actual work on the contract may be said to have only commenced in February last, for everything that was done before that time was valueless as product, though giving a very considerable experience to the manufacturers. Since that time the work has progressed quite satisfactorily.

It speaks well for the company and their reliability that they persisted in their endeavors to complete the contract, even at a loss, and did not give it up in despair; while their thanks are due to the Department for continued reliance in their ability in the face of poor results and for the forbearance that allowed and encouraged them to proceed.

As the company owns a very fine new emery testing-machine of 300,000 pounds capacity, they, very early in the life of the contract, requested that the specimens taken from the hoops should, to save time, be tested at their works in the presence of the inspector. After many comparisons between their machine and the one at Watertown Arsenal had established the fact that reliable results could be obtained from tests at Johnstown you were pleased to allow the company to test all but one of each set of specimens taken from the hoops, one of each set being sent to Watertown Arsenal for test and also for the determination of hardness and specific gravity.

At the present time twelve of the hoops have been accepted and rough finished, two others have shown satisfactory partial test, and the remainder are in a forward state of completion, all but one being forged and under treatment.

A summary of the results obtained in test of specimens taken from these hoops is given below

Results of tensile test of tangential specimens from hoops for 10-inch steel breech-loading rifle.

[Length of specimen, 6 inches; sectional area, 0.25 of a square inch.]

Mark of hoop.	Number of specimen.	Position of specimen.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
			Pounds.	*Inch.*	*Pounds.*	*Per cent*	*Per cent.*		
A$_2$	1	Middle	58,000	.001975	100,120	16.33	36.8	....	......
A$_2$	2	Outside..............	58,000	.001958	102,820	13.75	29.1	....	......
A$_2$	3	Middle	60,000	.002037	98,800	14.83	32.7	....	......
A$_2$	4	Inside	59,000	.001967	100,600	17.00	47.2	7.8409	20.70
A$_4$*......	1	Middle	58,000	.002100	104,240	14.00	41.9	....	......
A$_4$*......	2	Outside..............	60,000	.002046	106,200	13.75	29.1	....	......
A$_4$	3	Middle	58,000	,002008	103,120	11.50	16.4	....	......
A$_4$*......	4	Inside	62,000	.002054	108,800	9.50	17.0	....	......
A$_4$	5	Middle	56,000	.001917	103,960	15.17	47.2	7.8438	22.14
A$_4$	6	Outside..............	60,000	.002013	104,640	15.60	37.7	....	......
A$_4$	7	Middle	55,000	.001842	102,600	14.66	35.3	....	......
A$_4$	8	Inside	58,000	.001958	106,480	10.83	32.1	....	......
A$_5$*......	1	Middle	55,000	.001867	97,840	16.67	49.7	....	......
A$_5$	2	Inside	59,000	.001900	104,760	15.17	49.7	7.8424	20.70
A$_5$	3	Middle	55,000	.001837	100,960	16.33	38.2	....	......
A$_5$	4	Outside..............	58,000	.001946	104,840	14.58	35.6	....	......
A$_5$	5	Middle	54,000	.001846	101,320	16.42	43.8	....	......
A$_6$	1	....do	62,000	.002133	103,280	17.17	47.2	7.8402	21.89
A$_6$	2	Outside..............	64,000	.002171	104,640	13.67	29.5	....	......
A$_6$	3	Middle	61,000	.002067	100,080	15.08	33.7	....	......
A$_6$	4	Inside	63,000	.002158	104,400	14.50	39.8	....	......
B$_3$	1	Middle	50,000	.001567	92,400	13.30	19.7	....	......
B^3	2	....do	53,000	.001683	98,320	18.17	47.2	....	......
B$_3$	3	....do	57,000	.001967	104,840	13.50	39.2	7.8409	22.90
B$_3$	4	Outside..............	58,000	.001958	107,840	12.00	35.6	....	......
B$_3$	5	Middle	53,000	.001758	100,840	16.00	37.6	....	......
B$_3$	6	Inside	54,000	.001825	101,640	12.90	32.4	....	......
B$_4$	5	Middle	61,000	.002100	108,120	16.50	49.7	7.8432	24.26
B$_4$	6	Outside..............	55,000	.001833	101,160	13.75	42.5	....	......
B$_4$	7	Middle	57,000	.001921	104,160	13.17	36.2	....	......
B$_4$	8	Inside	59,000	.001954	104,880	11.50	39.2	....	......
B$_5$*......	1	Middle	54,000	.001800	102,000	15.33	44.6	....	......
B$_5$	2	....do	57,000	.001950	106,440	12.67	39.2	7.8488	24.26
B$_5$	3	Outside..............	58,000	.001896	104,120	14.58	37.8	....	......
B$_5$	4	Middle	55,000	.001637	100,240	14.00	42.8	....	......
B$_5$	5	Inside	58,000	.001958	105,880	11.67	40.5	....	......
B$_7$*......	1	Middle	63,000	.002063	107,200	11.83	31.9	....	......
B$_7$	2	....do	62,000	.002050	109,560	15.38	44.6	7.8419	21.64
B$_7$	3	Outside..............	64,000	.002137	108 400	15.33	47.1	....	......
B$_7$	4	Middle	58,600	.001954	106,400	17.10	41.9	....	......
B$_7$	5	Inside	63,000	.002083	112,240	12.00	42.5	....	......
C$_1$†	1	....do	68,000	.002300	108,720	15.50	30.6	....	......
C$_1$	2	Middle	64,000	.002133	110,040	15.50	47.2	7.8376	24.83
C$_1$	3	....do	62,000	.002071	110,820	14.50	25.8	....	......
C$_1$	4	....do	65,000	.002167	111,480	16.00	33.3	....	......
C$_1$	5	Inside	68,000	.002267	112,760	15.00	35.6	....	......
C$_3$	1	Middle	62,000	.002167	110,000	16.33	49.7	....	......
C$_3$	2	Outside..............	66,000	.002213	117,200	11.33	33.2	....	......
C$_3$	3	Middle	65,000	.002183	115,340	12.00	25.5	....	......
C$_3$	4	Inside	63,000	.002100	101,400	13.66	46.7	....	......
D$_1$	1	Middle	57,000	.001867	100,240	15.33	39.2	7.8438	21.40
D$_1$	2	Outside..............	59,000	.001983	103,920	13.50	33.8	....	......
D$_1$	3	Middle	54,000	.001787	98,520	14.67	29.5	....	......
D$_1$	4	Inside	56,000	.001909	100,560	17.42	45.2	....	......

* Not accepted on these results; retempered and annealed.
† Rejected on account of defect; new hoop made.

FORGINGS FOR THE PARTS OF A 7-INCH STEEL BREECH-LOADING HOWITZER.

These parts include tube, jacket, sleeve, base ring, key ring, breech block, obturator stem, lever handle, nut, carrier ring, and trunnion hoop, of the following rough-finished dimensions:

Nature of piece.	Interior diameter.	Exterior diameter.	Length.	Remarks.
	Inches.	*Inches.*	*Inches.*	
Tube	6.6	12.1	87.15	
Jacket	10.6	16.9	30.15	
Sleeve	10.6	15.4	25.25	
Base ring	7.4	12.66	7.8	
Key ring	9.8	12.4	1.75	
Breech block	1.0	9.0	12.0	With projection.
Obturator stem		7.5	2.25	
		2.25	11.0	
Lever handle		2.0	16.0	
Nut		2.25	1.25	
Carrier ring	8.1	12.0	2.0	With projection.
Trunnion hoop	10.5	16.9	17.75	With rimbases and trunnions.

The forgings to be of open-hearth steel of American production, oil tempered, and afterwards annealed, and to have the following physical qualities:

Tube	Elastic limit 42,000 pounds per square inch. Tensile strength, 88,000 pounds per square inch. Elongation after rupture, 20 per cent.	The results of the test of no one specimen to be below—	Elastic limit, 36,000 pounds per square inch. Tensile strength, 80,000 pounds per square inch. Elongation, after rupture, 17 per cent.
Jacket, sleeve, breech block, base ring, and other small forgings.	Elastic limit, 52,000 pounds per square inch. Tensile strength, 95,000 pounds per square inch. Elongation after rupture, 18 per cent.	The results of the test of no one specimen to be below—	Elastic limit, 46,000 pounds per square inch. Tensile strength, 88,000 pounds per square inch. Elongation after rupture, 15 per cent.
Trunnion hoop	Elastic limit, 48,000 pounds per square inch. Tensile strength, 95,000 pounds per square inch. Elongation after rupture, 15 per cent.	The results of the test of no one specimen to be below—	Elastic limit, 43,000 pounds per square inch. Tensile strength, 85,000 pounds per square inch. Elongation after rupture, 12 per cent.

Work under this contract has progressed so far as the forging and treatment of the smaller parts; the forging and rough turning and boring of the tube and sleeve, and the partial forging of the trunnion hoop.

APPENDIX 25.

PROGRESS REPORT ON CONSTRUCTION OF 10-INCH B. L. RIFLE, CAST IRON, WIRE-WRAPPED. BY LIEUT. WILLIAM CROZIER, ORDNANCE DEPARTMENT.

(3 plates.)

WATERTOWN ARSENAL,
Watertown, Mass., August 13, 1886.

SIR: I have the honor to submit the following progress report upon the construction of the 10-inch wire-wrapped cast iron rifle recently in progress of manufacture at this arsenal.

The report is divided into five parts, as follows:

Part I. The gun.
Part II. The plant.
Part III. The materials.
Part IV. The tensions, shrinkages, and other theoretical considerations.
Part V. The practical operations.

PART I.

This gun first made its appearance, as far as known to the writer, as one of several designs proposed by Dr. W. E. Woodbridge, submitted by the Chief of Ordnance to the Board of officers appointed under act of Congress approved March 3, 1881, generally known as the Getty Board on Heavy Ordnance.

As described by Dr. Woodbridge and represented in the drawings submitted, the gun had a powder-chamber of about 11 inches diameter, a thickness of cast-iron over the powder-chamber of about 8.25 inches, and of wire over this about 6 inches. The wire to have a tensile strength of at least 150,000 pounds to the square inch, and to be "wound under a tension of 50,000 pounds or more to the same area." The length of the gun to be 25 calibers. The wire-wound portion extended only as far forward as the trunnions. The wires to be soldered together after winding by immersing the whole in a bath of solder of low fusibility.

The Board before mentioned recommended the construction and test of a cast-iron gun wound with wire, upon Dr. Woodbridge's plan, for the following reasons:

(1) Experience thus far gained with similar guns promises for the construction success within the usual limits of powder pressure.

(2) They can be readily and rapidly reproduced in this country without incurring the delay of sending to foreign countries for large masses of forged steel.

* * * * * * * *

But while this latter class (built up steel) of gun is being developed through a series of careful and costly experiments, some cheaper gun, though of less power, susceptible of rapid reproduction in case of need, should be determined upon, so that the country may not be left entirely defenceless.

The gun was again referred to in the report of the select committee on heavy ordnance, appointed under Senate resolution of August 2, 1882, in the following language:

We recommend the making of such number of cast-iron guns banded with steel bands or wrapped with wire, as may be necessary to fully and thoroughly test their efficiency.

A drawing was sent to this arsenal for construction, subsequently to which the design was modified as follows:

The base band A, Plate I, was shrunk on with a taper of .05 inches, instead of being screwed on with a shrinkage.

The ring F was shrunk on with a plain cylindrical surface, instead of a screwed one.

The additional ring G was screwed on in front of ring F.

After the winding was completed, and before the rings were shrunk on, the wire-wound portion was to have been incased in boiler iron and the gun placed horizontally in a soldering furnace, where it was to be heated to the proper temperature, melted solder poured into the case, and the gun slowly revolved to facilitate the penetration of the solder into and through the mass of wire. The soldering operation was omitted, experiment with a trial cylinder having shown it to be of doubtful desirability and impracticable by the method proposed.

THE GUN

As built is shown in Plate I.

The body is of cast iron. The thickness of cast iron over the powder chamber is 9.835 inches, under the trunnion band it is 8.96 inches, under ring F 10.475 inches, under ring G 9.80 inches. Forward of ring G for a distance of 28 inches the thickness decreases on a curve whose ordinates are given, from the end of which it runs down on a straight taper to the muzzle where it is 4.5 inches.

The wire is wound to a thickness of 5.49 inches over the powder-chamber and 3.957 inches under the trunnion band and sleeve. In the shallow recess extending from a little in rear of the trunnion band to the forward end of the sleeve the tension of application of the wire was 7,715 pounds per square inch; for the remainder of the wire it was 41,000 pounds per square inch. At the breech end the wire abuts against a steel spool ring, B, which is screwed upon the gun-body. The curved space at the rear of the recess in the body is filled up and given flat surfaces for winding against by a wrought-iron filling ring, which is in two parts, jointed as shown in Plate I. At the front the wire abuts against a ring composed of two concentric rings: the inner one, of wrought-iron, is in two parts, with straight radial joints, it serves to fill up the curved space in the body of the gun, and is held together by the outer steel ring, E, which is screwed upon it. The outer portion of the wire over the powder-chamber abuts at the front end against the trunnion band. All of the spool and filling rings were put on cold.

The steel ring A was bored with a conical hole, the larger diameter in rear, the difference of diameters being .05 inch. It was put on with a shrinkage of .0484 inch, equal to .00165 inch per inch of diameter. The trunnion ring C, of steel, was put on with a shrinkage of .0368 inch, equal to .00102 inch per inch of diameter, the sleeve D with .0228 inch, equal to .0006 inch per inch of diameter, the ring F with .0444 inch, equal to .00148 inch per inch of diameter. These shrinkages, except for the trunnion band, are slightly different from the theoretical ones, as will be explained later.

The front part of ring F is cut away on the outside for the purpose of easing off the pressure on the cast-iron body.

The ring G is to be made as near a fit as practicable, and screwed on cold.

The diameter of the rifled part of the bore across the lands is 10 inches, across the grooves 10.12 inches, the grooves thus being .06 inch deep. That of the shot-chamber from the front edge of the band to the base of the projectile is 10.20 inches; that of the powder-chamber 10.85 inches. The length of the powder-chamber from the front end of the breech-block recess to the base of the projectile is 56.25 inches; that of the bore from the base of the projectile to the muzzle 227.25 inches. The total length of the gun is 300.75 inches, or 30.075 calibers. The form of the front end of the powder-chamber is shown in Plate I.

THE RIFLING.

The twist of the rifling increases from 1 turn in 120 calibers at the origin to 1 turn in 35 calibers at 10 inches from the muzzle, from which point to the muzzle it continues at the same rate. The developed curve is a semi-cubical parabola whose equation, referred to an element of the bore and the developed section at the origin of the rifling, is,

$$(y+.35256)^2 = .00001508(x+20.2)^3$$

The number of lands and grooves is 50. The lands are .18 and the grooves .4488 inches wide.

BREECH-MECHANISM.

The breech-mechanism is of the interrupted screw system, designed for use with a DeBang gas-check, and presents no new features.

The composition of the block-carrying tray is,

Copper	55
Zinc	44.5
Tin	.5
Total	100

This is completed except fitting to the gun.

WEIGHTS.

The weight of cast-iron body is 17 tons, that of the steel wire 9 tons, and of other steel parts 3 tons, making the total weight of the gun, exclusive of the breech mechanism, 29 tons. The axis of the trunnions passes through the center of gravity of the gun when the breech-block is inserted; thus the gun is without preponderance.

PART II.

The plant.

THE BUILDING.

The building in which are placed the winding lathe and the furnaces for soldering and tinning was erected for this purpose. It is a frame structure with a slate roof, 66 by 42 feet, with an extension 20 by 17 feet in the prolongation of the lathe, the latter made necessary by the

determination to bore and rifle the gun at this arsenal, not at first intended.

The building was commenced on October 22, 1884; the asphaltum floor was finished on January 20, 1885. Preparations for setting the lathe, building the furnaces, &c., were carried on concurrently with the erection of the building. A railroad track of the ordinary guage runs through the middle of the building lengthwise. The building is heated by steam.

THE SOLDERING FURNACE.

It was designed by Dr. Woodbridge.

The heating-chamber is an oven 370 inches long, 54 inches wide, and 66 inches high. Running along the bottom of the oven are two 9-inch I-beams resting on cast-iron supports, forming a railway for the trucks carrying the gun. Resting on the lower flanges of the I-beams and forming the floor of the oven is a sheet-iron diaphragm. The sides and top of the oven are plastered to a thickness of 1 inch with a mixture of fine molding sand and clay, wet with equal parts of water and molasses, to this being added as much fine sawdust and chopped manila rope as would work well, the whole being thoroughly worked together. This plaster was supposed to have very little conductive power and little tendency to crack at the temperature employed.

For the purpose of determining the temperature of the oven there were to be hung within it eight mercury thermometers, opposite to glass-covered apertures or peep-holes. Six of these were distributed at equal distances along the side of the oven near the top, the remaining two being lower down and near the ends. They are marked *h* in the drawing. Small cranks, worked from the outside, served to move the thermometers up and down, so as to expose a sufficient length of their scales.

The ends of the oven were closed by cast-iron doors covered with the plaster before described.

Without the furnace are projections, marked W, in which to rest windlasses for hauling the gun in and out.

Below the floor of the oven and distributed equally along its length are six fire-places, with brick sides and cast-iron tops; each cover being made of separate plates, so that they might slide over each other under the expansive action of the heat.

Connecting with each fire-place is a 5-inch pipe, running into a 6-inch pipe at the rear, and finally leading through an 8-inch pipe to the flue.

The fuel was charcoal, at first intended to be burned directly on the floor of the fire-place, but trial having shown it to be difficult to attain the proper temperature at the ends of the oven, the end fire-places were provided with grates extending about half way across.

When burnt upon the floor the charcoal was passed through the upper door and burned in a little pile covering the damper.

For introducing the solder, holes were left at intervals along the top of the oven; they were covered by a casting shaped like a bucket and filled with the plaster mixture.

A continuation of the I-beam railway was provided, extending for a sufficient distance in front of the furnace to rest the trucks and gun upon it, preparatory to running them into the oven.

The gun, while in the oven, was to have been revolved by means of a shaft projecting through the door, to which was keyed a worm-wheel rotated by suitable gearing and pulley from overhead shafting.

To convey the melted solder over the furnace, an overhead crane was provided, running its entire length.

This furnace was used in an attempt to solder a trial cylinder, assembled in connection with the construction of this gun. The attempt not having proved successful, it was abandoned with reference to the gun, and the furnace became useless for the purpose for which it was intended.

THE SHRINKING APPARATUS.

When, in the course of the construction of the gun, the operation of shrinking on the hoops was reached, it became necessary to devise some means of heating them, and for this purpose one end of the soldering furnace was utilized.

A brick wall was built, partitioning off at one end of the oven a heating-chamber 83 inches long. The fire-place at this end was torn out and a new one built in, with a grate for burning anthracite coal. The door and damper were changed, larger ones being substituted. The draught-pipe was enlarged. The large end door was fitted with counterweights, and arranged to slide vertically. A short prolongation of the I-beam railway was arranged, for the truck carrying the ring to be run in and out upon.

The overhead crane was utilized to lift the heated ring from the truck and carry it into place on the gun. Also to carry the "following ring" for pressing the hoop, while cooling, up to its place.

The fuel used was chestnut anthracite coal.

The principal other shrinking appliances are those for producing a tight joint between a ring and the shoulder against which it is to rest.

Two large castings, *a* and *b*, rest, one against a shoulder on the gun, and the other against the ring being placed. Between these castings extend four wrought-iron rods, *r*, each 3.5 inches square, one end of each rod being threaded for a nut. While the ring is being heated in the furnace, these rods are expanded by the flame of gas-burners *g*. As soon as the ring is in place on the gun, the casting *h*, or following ring, is brought up against it, the rods slipped into place, and the nuts screwed up.

The contraction of the rods upon cooling pulls the following ring against the hoop with such force as to keep it pressed up to its place. The amount of force is regulated by a gauge which rests against the end of the rod and the face of the nut. The rod being expanded more than necessary, the nut is placed so that the gauge fits, thus restraining the rods from contracting to their cold lengths by a fixed amount.

The operation of shrinking on a hoop is as follows:

The hoop is in the heating-chamber, placed horizontally upon the truck, and encircled by an iron band with an eye in it for lifting. The door is closed. The following ring is suspended from the overhead crane, above and in front of the door of the heating-chamber. The chain fall for lifting the hoop hangs from the overhead crane in a convenient position. The gun is directly in front of the heating-chamber, supported on blocking. As some of the rings in going to their positions had to pass the center of gravity of the gun, the latter had to be counterweighted to prevent it from tipping. A 9 inch I-beam was passed into the powder chamber, a fit being obtained by perforated wooden plugs. On this I-beam was hung an old cast-iron 8 inch gun.

The upper rods of the press are drawn up into the position for heating, and retained by ropes tied with slip-knots. The lower ones are swung out sufficiently and rest upon greased iron bars. To each rod its own gauge, properly marked for setting the nut, is attached by a thread. The gas under the rods is burning; their expansion has been

measured and found to be more than sufficient. The water-sprinkling ring for cooling the hoop is on the gun near its position for use. Two watering-pots for cooling off the rods of the press stand full of water near by, a supply of water in barrels being convenient.

The diameter of the hoop has been measured by means of a measuring-rod attached to the end of a long stick, passed in through an aperture, uncovered for the purpose, in the door of the heating-chamber.

At the command the door is opened by a man on top of the furnace, the truck is pulled out, the diameter of the hoop verified, the hook of the falls engaged in the eye of the band encircling the hoop, and the hoop raised. As soon as it is at the proper height the carriage is pulled forward on the traveling crane by a rope attached to the carriage and passing through a pulley at the end of the crane. The hoop is guided by two men. As soon as the hoop is clear of the truck, the following ring is lowered and pulled forward after the hoop. The hoop being up against its shoulder the following ring is brought up against it, the gas pipes pulled from under the press rods, the lower rods slid into place and the upper ones lowered, the nuts set in proper positions by means of the gauges, the threads holding the latter to the press rods being snapped. The nuts being adjusted the rods are immediately cooled off with the watering-pots. As soon as the sprinkling of the rods is commenced the water is turned on in the water-ring and the gun immediately in rear of the hoop kept cool. This ring is afterwards advanced to the rear edge of the hoop and subsequently over the entire hoop.

Eleven men are required, each one of whom is of course thoroughly instructed in his duties, and all several times drilled in the operation.

For shrinking the sleeve a gas ring was also used, a circle of burners keeping the forward end warm until the rear end had clamped the gun.

THE LATHE

was brought from Frankford arsenal, where it had been used in the construction of the brazed 10-inch wire gun finished in 1876.

It is now, the head-stock having been raised, capable of swinging a piece 61 inches in diameter and 456 inches long. It is not built as a modern lathe of its capacity would be; the ways are too light and the carriage attachments are not up to date. Still it has proved and is a serviceable tool.

The additions for boring and rifling the gun were made at this arsenal, the design being by Mr. H. P. Elwell, draughtsman.

The bar is of cast iron, 9.75 inches in external diameter. It is hollow, in two pieces joined together. It rests in bearings on two deep I-beams, which are supported on castings, *d*, part of which rest on the ways of the lathe and part on a continuation of the ways formed of I-beams joined together by transoms and resting on masonry supports.

For boring, the gun is revolved, and the bar is fed forward by a screw which runs along its axis. The screw is revolved by a worm-gear, the motion being derived from bevel-gears and a shaft running from the head-stock, between the ways, directly under the axis of the lathe. A cutter-head carrying seven cutters is used.

In rifling, the gun is stationary, and the bar is moved forward by the same screw, but a more rapid motion is given than is possible with the worm-gear by a gear and friction pulleys at the end of the bed *b*. The friction-pulleys are run by a belt from overhead shafting, which again is run by a pulley on the shaft between the ways.

As the bar moves forward the motion of rotation to produce the rifling curve is given by an inclined rack resting in a gear on the rear end of the bar. The lower end of the rack is constrained to follow the line of a steel bar bent into a curve whose ordinates bear the same ratio to those of the developed rifling curve that the diameter of the gear in which the rack rests bears to that of the bore of the gun.

To turn the bar into position for cutting another groove the connection between the gear and bar is released, the bar turned with a wrench, and the connection again made.

The connection is as follows: A hollow disc or ring is fastened immovably to the bar. In the outer periphery of the disc are notches something like the teeth of a gear. By an ingenious device operated by an eccentric, a piece attached to the gear is caused to descend into one of these notches, and while there locks the gear and bar together. When the bar is turned so that the piece occupies a different notch, the tool is in position for cutting another groove.

This apparatus has not as yet been used.

THE WINDING MACHINE.

(Plate II.)

In the patented invention of Dr. W. E. Woodbridge, the base A, Plate II, is a large casting bolted to the carriage of the lathe. Resting on this is the cast-iron frame B, to which are attached the parts of the machine. The machine is double, winding two wires at a time; the parts on each side of the frame are exactly alike.

The wire is carried on reels. They are mounted on a truck which is connected with the carriage of the lathe, and runs on the railroad track through the center of the building.

From the reel the wire runs to the guide-rolls *a*. These are small revolving wheels of steel, with triangular grooves in their perimeters, so that the two together fit the square wire. They are movable, and by an eccentric their distance apart can be regulated so as to accommodate wire of different sizes. They are so placed that the wire passing from between them enters straight between the initial friction-clamps *b*.

The lower clamp is fixed, the upper one is pressed down upon the wire by a screw, *c*, acting through the medium of the spring *d* and the bar *e*. The upper clamp is kept from sliding along on the wire by the small projecting piece *p*. Strips of boxwood between the clamps form the surfaces between which the wire slides. These strips again rest upon strips of rubber, so as to secure a perfectly even bearing.

From the friction-clamps the wire passes around the disc *f*, the number of turns about the disc depending upon the degree of tension desired. For 41,000 pounds per square inch, the tension employed in winding the gun, three turns were required. The tension produced by the initial friction-clamps is greatly increased by the wire thus sliding around the disc.

From the disc the wire passes over the rolls *h* to the gun, which is rotated in the lathe.

The disc *f* is pivoted at *g*, but is restrained from rotating by the jointed bar *i*. This bar terminates in a disc, *k*, perforated for the free passage of the screw *l*, and engages over the point of one of the weighing springs *m*. The other point of the weighing springs is retained by the piece *n*, fastened to the screw *l*, which in turn is held by the nut *o*, resting against the frame B.

Suppose the gun to be started revolving, there being any pressure on the wire between the friction-clamps *b*. The whole system of clamps and disc moves forward, carrying the movable point of the weighing springs at *k* towards the fixed point at *n*, until an equilibrium is produced by the tension of the weighing springs becoming equal to the tension with which the wire is passing to the gun, when the wire continues to slide without further motion of the system. The degree of tension is indicated by the scale attached to the fixed piece *n*, the pointer being attached to the bar *i*. The scale has been graduated empirically by means of weights. Suppose now, that, from some irregularly acting cause, the tension with which the wire is going to the gun is increased, the system moves forward, further compressing the weighing springs, the disc *f* rotates about the point *g*, the point *r* rises, carrying the bar *s*, which through the nut *t* raises the bar *e*, relieving the pressure of the friction-clamps *b* upon the wire. The machine is thus to a certain extent self-regulating.

The rolls *h* are set at such a height that the wires in passing over them are given a proper permanent bend, to conform to the curvature which they are to assume on the gun. The upper roll is so mounted as to be movable to the right or left. The wire passing over it is in advance, whether the winding is progressing from right to left or *vice versa*. Thus both wires are wound up to the shoulder on the gun, and the triangular spaces at the ends of each layer are decreased. These spaces are filled with tapered wires.

The clamps C are for the purpose of holding the wires when, for any reason, the hold of the friction-clamps *b* is released.

The boxwood strips in the friction-clamps are, before being finished, thoroughly soaked in melted beeswax.

About the disc *f* is placed a strip of manila paper, to form a surface for the wire to slide upon. This paper is prepared by thorough soaking in melted beeswax, and subsequent careful draining.

Mounted on the traveling carriage, on the opposite side of the gun from the winding machine, is a tool post from which a bar extends over the gun, carrying on its end a roll for keeping the wire, as it is laid on, pressed laterally against that previously wound.

This machine does not fulfill the conditions requisite in a good winding machine. Its accuracy cannot be relied upon as being within a less limit of error than 15 pounds. This although not important with wire of the size used, might become so with smaller wire. But the great objection is the slowness with which it requires the wire to be laid on. The rate of the moving wire cannot much exceed 10 feet per minute, and even at this rate the progress of winding is subject to frequent interruptions and delays. The paper surrounding the disc wears rapidly, and when it is not in proper condition the wire moves with a jerky, irregular motion which soon becomes so violent as to endanger the machine and to necessitate stopping to change the paper.

Various substances have been tried as substitutes for the paper, but none decrease the evil of violent vibration, and only one—a press paper—has an appreciably greater durability than the manila paper. The press paper is now being used and probably will be in the future.

The difficulty mentioned increases with the speed and with the tension of application, and it is doubtful whether the machine in its present state will answer for the high tensions required for other guns.

The operator has to sit with his hand constantly on the regulating-screws.

It would be desirable in winding cylinders of greater diameter than about 25 inches to wind more than two wires at a time. This might perhaps be effected with a machine similar in principle to the present one.

The capacity of the wire-carrying reels is too small; they might easily carry double the amount of wire, which would necessitate stopping to change them only half as often.

A great advantage claimed for wire guns over those built up by shrinkage is economy of construction. If this feature is to be realized, a new machine will have to be procured or the present one so modified as to lay on the wire with much greater rapidity than is now attainable. The average progress has been the application of about one-half of a layer per day. Nothing less than five times this rate should be considered satisfactory.

PART III.

THE MATERIALS.

The contract for the body was made on September 24, 1883. It was cast on March 14, 1884, and inspected on August 29 of the same year.

The casting was made breech downward, with an excess in length of about 15 inches, to be cut off for experimental purposes. (Appendix 23, Report of the Chief of Ordnance for 1885.)

The mean tensile strength is 32,000 pounds per square inch and the specific gravity 7.28. Records of tensile and compressive tests are appended, marked respectively B and C.

An experiment with the cylinder cut from the breech end showed the bore of the powder-chamber to be under initial compression, due to the cooling of the casting, of about 4,200 pounds per square inch; the exterior to be under compression of about 306 pounds per square inch, and the circle of diameter 26 inches, to be under extension of about 1,800 pounds per square inch.

The metal seemed to possess the usual qualities of good gun-iron.

THE WIRE

Was drawn from open-hearth steel billets, 2 inches square and weighing about 80 pounds each. It is of square cross-section, .15 of an inch on a side, with the corners rounded to a radius of .01 of an inch.

Contract for the steel billets was made with the Otis Iron and Steel Company on December 18, 1883. The metal of the billets was to have a tenacity of not less than 70,000 pounds per square inch, with an ultimate elongation of 30 per cent. and contraction of area of 50 per cent. When drawn into wire it was expected to have a tenacity of 160,000 pounds, an elastic limit of 100,000 pounds, and sufficient ductility to enable it to be wrapped about itself.

Contract for drawing the billets into wire was made with the Trenton Iron Company on June 30, 1884. The drawing was to have been completed six months after the delivery of the billets, which was made on September 18, 1884, but the time was extended until September 20, 1885.

Reports of Lieut. William M. Medcalfe, Ordnance Department, from which the above information was obtained, describing the process of manufacture of the billets and drawing into wire, may be found in the reports of the Chief of Ordnance for 1884–'85.

The specific gravity of the tinned wire is about 7.81.

The wire is defective in the quality of ductility, but this defect has not interfered with its application to the gun. The latter operation has, however, been much retarded by the occurrence of numerous local defects in the wire which cause it to break with a peculiar fracture, one side terminating in a long conical point which is often discolored, as with rust, indicating that the metal was not continuous. Sometimes the presence of such a flaw is indicated by a crack at the corner of the wire. In certain cases the wire showed not more than one third of its section to be of good metal.

The wire is not by any means such as should in the future be used in gun construction.

THE RINGS.

Rings A, C, (trunnion ring), and F were procured from Sir Joseph Whitworth; the sleeve casting D and ring C from the Midvale Steel Company.

These pieces are all good, and undoubtedly possess greater strength than is required of them in the positions which they occupy.

The breech block, spindle, and lever forgings, were from the Midvale Steel Company.

PART IV.

THE TENSIONS, SHRINKAGES, AND OTHER THEORETICAL CONSIDERATIONS.

The wire was laid on with uniform tension. The result is not a uniform extension of the wire under fire, but, owing to the relatively great thickness of the wire jacket, the greatest strain to which the wire is subjected is considerably within its elastic limit. The uniform tension is chosen because it is admissible and most convenient. The wire being wound so as to produce a given pressure upon the core, all effects upon the core are independent of the style of tension employed.

THE FORMULAS USED.

The formulas appertaining to the effects of the wire and which refer to the state of rest have been given in the report upon the experimental cylinder assembled preparatory to the construction of this gun.

Most of those formulas are to be found in the work by Mr. James A. Longridge, entitled "A Treatise on the Application of Wire to the Construction of Ordnance." The deductions are, however, different from, and, it is hoped, clearer than those given in the above-mentioned work.

The following are, as far as known to the writer, original with him:

Formula for extension of wire wound with uniform tension.

Formula for pressure produced by winding with uniform tension on a core composed of two concentric cylinders of different moduli of elasticity.

We will adopt the following nomenclature:

R_0, R_1, R_2, &c. = Radii of cylindrical surfaces proceeding from the bore outward.

P_0, P_1, P_2, &c. = Pressures at these surfaces under fire.

P_0^1, P_1^1, P_2^1, &c. = The same at rest.

p_0, p_1, p_2, &c. = The changes of pressure at these surfaces due to firing.

θ_0, θ_1, θ_2, &c.=Limits of elasticity of the metal of the successive cylinders under extension.

ρ_0, ρ_1, ρ_2, &c.=The same under compression.

T_1, T_2.=The constant tension of winding.

ε_0, ε_1, ε_2, &c.=The moduli of elasticity of the different cylinders.

The formula giving the relation between the tension of winding and the normal pressure produced by it upon the core is—

$$P_1{}^1 = \frac{T_1}{\beta+1} l^* \frac{(\beta+1)n^2-(\beta-1)}{2} \qquad A.$$

in which

$$\beta = \frac{\varepsilon_1}{\varepsilon_0}, \frac{R_1{}^2+R_0{}^2}{R_1{}^2-R_0{}^2}, \frac{\varepsilon_1-\varepsilon_0}{3\varepsilon_0}$$

$$n = \frac{R_2}{R_1}$$

For the tangential extension of the wire at rest

$$\frac{\Delta r}{r} = \frac{T_1}{\varepsilon_1}\left\{1 - \frac{2(\beta-1)+(\beta+1)\frac{r^2}{R_1{}^2}}{3(\beta+1)\frac{r^2}{R_1{}^2}}\, l\, \frac{(\beta+1)n^2-(\beta-1)}{(\beta+1)\frac{r^2}{R_1{}^2}-(\beta-1)}\right\} B.$$

in which r is any radius in the wire cylinder.

For the rate of radial extension in the wire at rest

$$\frac{d\Delta r}{dr} = \frac{T_1}{3\varepsilon_1}\left\{\frac{5(\beta+1)\frac{r^2}{R_1{}^2}+(\beta-1)}{(\beta+1)\frac{r^2}{R_1{}^2}-(\beta-1)} + \frac{2(\beta-1)-(\beta+1)\frac{r^2}{R_1{}^2}}{(\beta+1)\frac{r^2}{R_1{}^2}}\, l\, \frac{(\beta+1)n^2-(\beta-1)}{(\beta+1)\frac{r^2}{R_1{}^2}-(\beta-1)}\right\} C.$$

In order to produce the desired compression of the bore, the wire in the shallow depression under the trunnion ring was wound with a uniform tension different from that under which the remainder of the wire was applied. The wire wound over that in this depressed portion was then applied to a compound cylinder composed of two concentric cylinders, the inner one of cast iron and the outer one of steel.

The formula for the normal pressure produced, not having been previously established will now be deduced.

Suppose the wire to be wound upon the compound cylinder to a radius r, producing at the surfaces of radii R_1 and R_2 pressures denoted by ψ_1 and ψ_2, then to be continued to any other radius r^1, the pressures becoming $\psi_1{}^1$ and $\psi_2{}^1$, with a pressure at r, produced by the additional winding, which denote by ψ_r.

* l denotes the Napierian logarithm.

The changes at R_1 and R_2 are $\psi_1'-\psi_1$ and $\psi_2'-\psi_2$, respectively. $\psi_1'-\psi_1$ produces in R_1 a change per unit of length equal to—

$$-\frac{(4R^2_0+2R^2_1)(\psi_1'-\psi_1)}{(R_1^2-R_0^2)\varepsilon_0}$$

(Eq. 23, Notes on Construction of Ordnance, No. 35.)

$\psi_1'-\psi_1$ and $\psi_2'-\psi_2$ produce in R_1 a change per unit of length equal to—

$$\frac{(4R_2^2+2R_1^2)(\psi_1'-\psi_1)-6R_2^2(\psi_2'-\psi_2)}{(R_2^2-R_1^2)\varepsilon_1}$$

(Eq. 9 of same note.)

These changes are equal since the surfaces remain in contact, therefore—

$$-\frac{(4R_0^2+2R_1^2)(\psi_1'-\psi_1)}{(R_1^2-R_0^2)\varepsilon_0}=\frac{(4R_2^2+2R_1^2)(\psi_1'-\psi_1)-6R_2^2(\psi_2'-\psi_2)}{(R_2^2-R_1^2)\varepsilon_1} \qquad 1$$

Equating similarly the expressions for the relative change in R_2. (Eq. 21 of same note.)

$$\frac{4R_1^2(\psi_1'-\psi_1)-(4R_1^2+2R_2^2)(\psi_2'-\psi_2)}{(R_2^2-R_1^2)\varepsilon_1}=\frac{(4r^2+2R_2^2)(\psi_2'-\psi_2)-6r^2\psi r}{(r^2-R_2^2)\varepsilon_2} \qquad 2$$

solving (1) with respect to $\psi_1'-\psi_1$.

$$\psi_1'-\psi_1=\frac{6\varepsilon_0(R_1^2-R_0^2)R_2^2(\psi_2'-\psi_2)}{\varepsilon_1(R_2^2-R_1^2)(4R_0^2+2R_1^2)-\varepsilon_0(R_1^2-R_0^2)(4R_2^2+2R_1^2)}=A(\psi_2'-\psi_2) \qquad 3$$

substituting this in (2), solving with respect to $\psi_2^1-\psi_2$ and reducing—

$$\psi_2'-\psi_2=\frac{6(R_2^2-R_1^2)\varepsilon_1 r^2\psi r}{[(4R_1^2+2R^2_2-6AR_1^2)\varepsilon_2+4(R^2_2-R^2_1)\varepsilon_1]r^2-[(4R_1^2+2R_2^2)R_2^2-6AR_1^2R_2^2]\varepsilon_2+2(R_2^2-R_1^2)R_2^2\varepsilon_1}$$

$$=\frac{6(R_2^2-R_1^2)\varepsilon_1 r^2\psi r}{Br^2+DR_2^2} \qquad 4$$

if τ is the mean tension of the wire between r and r'.

$$\psi_r r=(r'-r)\tau$$

$$\psi_r=\frac{(r'-r)\tau}{r} \qquad \text{and}$$

substituting this value of ψ_r in (4) and dividing by $(r'-r)$

$$\frac{\psi_2'-\psi_2}{r'-r}=\frac{6(R_2^2-R_1^2)\varepsilon_1 r\tau}{Br^2+DR_2^2} \qquad 5$$

Passing to the limit of both members of (5) by unwinding the wire until r' becomes equal to r.

$$\mathrm{L}\left(\frac{\psi_2'-\psi_2}{r'-r}\right)_{r'=r}=\frac{d\psi_2}{dr}$$

$$\mathrm{L}\left(\frac{6(R_2^2-R_1^2)\varepsilon_1 r\tau}{Br^2+DR_2^2}\right)_{r'=r}=\frac{6(R_2^2-R_1^2)\varepsilon_1 rT_2}{Br^2+DR_2^2}$$

hence

$$\frac{d\psi_2}{dr}=\frac{6(R_2^2-R_1^2)\varepsilon_1 T_2 r}{Br^2+DR_2^2}$$

$$d\psi_2=\frac{6(R_2^2-R_1^2)\varepsilon_1 T_2 r\,dr}{Br^2+DR_2^2}$$

integrating

$$\psi_2=\frac{3(R_2^2-R_1^2)T_2}{B}\,l(Br^2+DR_2^2)+C$$

when $r=R_2$, $\psi_2=0$; hence

$$C=-\frac{3(R_2^2-R_1^2)T_2}{B}\,l(B+D)R_2^2$$

substituting

$$\psi_2=\frac{3(R_2^2-R_1^2)T_2}{B}\,l\frac{BR^2r^2+DR_2^2}{(B+D)R_2^2} \qquad 6$$

making in (6), $r=R_3$

$$P_2{}^1=\frac{3(R_2^2-R_1^2)T_2}{B}\,l\frac{B\frac{R_3^2}{R_2^2}+D}{B+D} \qquad D$$

in which

$$D=2(R_2^2-R_1^2)\varepsilon_1-[(4R_1^2+2R_2^2)-6AR^2]\varepsilon_2$$

$$B=(4R_1^2+2R_2^2-6AR_1^2)\varepsilon_2+(4R_2^2-R_1^2)\varepsilon_1$$

$$A=\frac{6\varepsilon_0(R_1^2-R_0^2)R_2^2}{\varepsilon_1(R_2^2-R_1^2)(4R_0^2+2R_1^2)+\varepsilon_0(R_1^2-R_0^2)(4R_2^2+2R_1^2)}$$

If $\varepsilon_1=\varepsilon_0$,

$$A=\frac{R_1^2-R_0^2}{R_2^2-R_0^2}\,\frac{R_2^2}{R_1^2}$$

If $\varepsilon_2=\varepsilon_1$,

$$B=6(R_2^2-AR_1^2) \qquad D=6R_1^2(A-1)$$

Formulas A, B, C, and D, are the only ones referring particularly to the effect of the winding which we shall need. By their aid and that of the general formulas relating to built up guns, as modified by Lieut. Rogers Birnie, jr., Ordnance Department, and which may be found in Notes on the Construction of Ordnance No. 35, we shall be enabled to solve all the problems relating to pressures and resistances, which will be considered.

The different sections of the gun give the following values for the constants:

TABLE I.—*Values of constants.*

	R_0	R_1	R_2	R_3	R_4
Under Ring A	6.78	14.86	20.35	....	....
In front of Ring A	6.78	14.86	20.35	....	....
Over powder chamber	5.425	14.86	20.35	....	....
In rear of trunnion ring	5	13.96	14.86	20.35	....
Under trunnion ring	5	13.96	14.86	18	23
Under sleeve	5	13.96	14.86	18	19.5
Under thick part of Ring F	5	15.475	20.35	....	....
Under thin part of Ring F	5	15.475	18.5	....	....
Under Ring G	5	14.39	17.44	....	....
In front of Ring G	5	14.39	....	....	....
At muzzle	5	9.50	....	....	....

	θ_0	$\theta_1=\rho_1$	$\theta_3=\rho_3$	ρ_0	e_0	e_1	e_2
	lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
Under Ring A	15,000	140,000	....	22,400	18,000,000	30,000,000	....
In front of Ring A	15,000	100,000	....	22,400	18,000,000	27,000,000	....
Over powder chamber	15,000	100,000	....	22,400	18,000,000	27,000,000	....
In rear of trunnion ring	15,000	100,000	....	22,400	18,000,000	27,000,000	....
Under trunnion ring	15,000	100,000	40,000	22,400	18,000,000	27,000,000	30,000,000
Under sleeve	15,000	100,000	40,000	22,400	18,000,000	27,000,000	30,000,000
Under thick part of Ring F	15,000	40,000	....	22,400	18,000,000	30,000,000	....
Under thin part of Ring F	15,000	40,000	....	22,400	18,000,000	30,000,000	....
Under Ring G	15,000	40,000	....	22,400	18,000,000	30,000,000	....
In front of Ring G	15,000	....	....	22,400	18,000,000	....	....
At muzzle	15,000	....	....	22,400	18,000,000	....	....

In the report upon the trial cylinder may be found diagrams constructed from the results of the tests of the cast iron, which indicate the values for the limits and modulus of elasticity of that metal.

The value for the modulus of elasticity of the steel wire was obtained by subtracting from each successive elongation per inch the corresponding permanent set for all loads from 20,000 to 40,000 pounds per square inch, and dividing 1,000 by the mean of them. (See Appendix A.)

Its limit of elasticity is placed at 100,000 pounds, and for that part of the wire which is free from flaws this is not too high, but as stated in describing the materials, it is so full of defects that no proper value can be assigned to this limit. The expression for it does not enter the formulas used. The wire is considered strong enough to withstand the greatest strain put upon it, which it will be seen is considerably less than 100,000 pounds. But all that can with certainty be said of it is that it will not part until the strain exceeds 41,000 pounds, the tension of winding.

The steel rings perform only a subsidiary part in the resistance of the gun, and the values of their limits of elasticity are selected as being within their known strength. They are not worked up to these limits. The modulus, 30,000,000, taken for them all is sufficiently exact for our purposes.

THE SECTION OVER THE POWDER CHAMBER.

The tension first selected by Dr. Woodbridge for winding this section was 45,000 pounds per square inch. But this was almost immediately modified to 41,000 pounds. The change being made for the reason that small thermometers applied to the wire indicated that the friction in passing through the winding machine elevated its temperature so as to produce an elongation equal to that due to a load of 4,000 pounds per square inch.

The following computations are made with the tension of application considered 41,000 pounds per square inch. Owing to the wire being applied to a cold surface, to the frequent stopping giving it opportunity to cool, and for other reasons, the writer does not believe that elevation of temperature produced an ascertainable effect on the tensions.

In formula (A), the terms have the following values,

$$T_1=41000 \text{ pounds.} \quad \beta=1.7946. \quad n^2=1.8754.$$

substituting these we find

$$P_1^1=11720 \text{ pounds.}$$

In order to ascertain the effect of this pressure upon the core we will use the formulas, taken from Notes on the Construction of Ordnance No. 35.

$$\frac{\Delta r}{r}=\frac{2(P_0 R_0^2-P_1 R_1^2)}{3(R_1^2 R_0^2)\varepsilon_0}+\frac{4 R_1^2 R_0^2 (P_0-P_1)}{3(R_1^2-R_0^2)\varepsilon_0}\cdot\frac{1}{r^2} \quad . \quad . \quad . \quad . \quad \text{E.}$$

$$\frac{d\Delta r}{dr}=\frac{2(P_0 R_0^2-P_1 R_1^2)}{3(R_1^2 R_0^2)\varepsilon_0}-\frac{4 R_1^2 R_0^2 (P_0-P_1)}{3(R_1^2-R_0^2)\varepsilon_0}\cdot\frac{1}{r^2} \quad . \quad . \quad . \quad \text{F.}$$

$$\frac{d\Delta h}{dh}=-\frac{2(P_0 R_0^2-P_1 R_1^2)}{3(R_1^2 R_0^2)\varepsilon_0} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{G.}$$

The first member of E represents the relative tangential distortion at any distance r from the axis. The first member of F the rate of radial distortion at the same distance from the axis, and the first member of G the relative distortion in a direction parallel to the axis, which is uniform throughout the thickness.

Making, in E and F, P=0

$$\frac{\Delta r}{r}=-\frac{1}{\varepsilon^0}\,\frac{2 P_1^1 R_1^2}{3(R_1^2 R_0^2)}\left(1+\frac{2 R_0^2}{r^2}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{H.}$$

$$\frac{d\Delta r}{dr}=-\frac{1}{\varepsilon_0}\,\frac{2 P_1^1 R_1^2}{3(R_1^2 R_0^2)}\left(1-\frac{2 R_0^2}{r^2}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{K.}$$

Substituting successively R_0 and R_1 for r in H and K, together with the value $P_1^1=11720$, we find

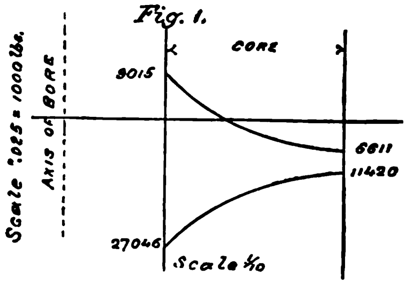
$$\Delta R_0=-''.0081514. \quad \frac{\Delta R_0}{R_0}=''.0015025. \quad \frac{\Delta R_0}{R_0}\varepsilon_0=-27046 \text{ lbs.}$$

$$\frac{\Delta R_1}{R_1}\varepsilon_0=11420 \text{ lbs.} \quad \frac{d\Delta R_0}{dR_0}\varepsilon_0=+9015 \text{ lbs.} \quad \frac{d\Delta R_1}{dR_1}\varepsilon_0=-6611 \text{ lbs.}$$

That is that the radius of the bore is contracted ″.0081514, or ″.0015025 per inch of its length. That this contraction represents a tangential compressive strain at the surface of the bore of 27,046 pounds per square inch, and at the exterior surface of the core of 11,420 pounds per square inch.

That the rate of radial distortion at the bore is a rate of elongation, and is equal to 9,015 pounds per square inch, and at the exterior surface of the core is a rate of compression equal to 6,611 pounds per square inch. The effect of the external pressure upon the core at rest is then represented by the curves below.

Fig. 1.



To these effects must be added those due to the initial tension produced by the cooling of the casting. The tangential compression at the bore from this cause is 4,200 pounds. (Report on trial cylinder.) The rate of radial elongation should be one-third of this or 1,400 pounds. Adding these to the above figures for the bore they become 31,246 pounds, and 10,415 pounds respectively. The bore being the dangerous surface, we need not now concern ourselves with the strains at other places.

THE STRAINS UNDER FIRE.

We will proceed under the supposition that the wire will withstand any powder pressure which is within the limit of endurance of the cast-iron.

From the last of Eq. 33. Notes on the Construction of Ordnance No. 35, we have, denoting the coefficient of P_0 by l.

$$p_1=\frac{6R_0^2\,\varepsilon_1\,(R_2^2-R_1^2)}{\varepsilon_1\,(R_2^2-R_1^2)\,(4R_0^2+2R_1^2)+\varepsilon_0\,(R_1^2-R_0^2)\,(4R_2^2+R2_1^2)}P_0 \qquad \text{L}$$
$$=lP_0$$

From Eq. 30 of same note

$$P_0^{(1)}=\frac{3(R_1^2-R_0^2)\theta_0+6R_1^2P_1}{4R_1^2+2R_0^2} \qquad \text{M}$$

$$P_0^{(2)}=\frac{3(R_1^2-R_0^2)\rho_0+2R_1^2P_1}{4R_1^2+2R_0^2} \qquad \text{N}$$

P_1 is equal to P_1^1+p. Making this substitution and combining L with M and N we deduce

$$P_0^{(1)}=\frac{3(R_1^2-R_0^2)\theta_0+6R_1^2P_1^1}{(4R_1^2+2R_0^2)-6R_1^2l} \qquad \text{O}$$

$$P_0^{(2)}=\frac{3(R_1^2-R_0^2)\rho_0+2R_1^2P_1^1}{(4R_1^2-2R_0^2)-2R_1^2l} \qquad \text{P}$$

$$l=(\bar{2}.9581929)^*$$

$P_0^{(1)}=29,376$ pounds.

$P_0^{(2)}=22,997$ pounds.

Of the above values that of $P_0^{(2)}$ being the smaller should be taken.

But let us see if we cannot obtain admissible values for P_0, which shall be greater than these rather unsatisfactory ones.

In O and P the values taken for θ_0 and ρ_0 were respectively 15,000 pounds and 22,400 pounds. Thus no account has been made of the initial compression of the casting due to cooling. This, as we have seen, places the bore in an initial state of tangential compression, represented by 4,200 pounds per square inch, and of radial elongation of 1,400 pounds per square inch. These numbers may then be added to θ_0 and ρ_0, making them respectively 19,200 and 23,800. With these changes we find

$P_0^{(1)}=32,310$ pounds.

$P_0^{(2)}=24,023$ pounds.

*The figures inclosed in brackets denote the logarithms of the corresponding numbers.

The value of $P_0^{(3)}$ is still small, but we must be content with it as the greatest which the theory of Clavarino will admit.

There are not wanting those who still oppose Clavarino and assert that under fire the tensile stress is all that need be kept within the limit of elasticity. The tensile stress at the bore produced by $P_0^{(3)}$ above is given by the formula

$$\frac{1}{\varepsilon_0}\left(P_0+\frac{t_0}{3}\right)=\frac{23800}{\varepsilon_0}$$

from which $t_0=-669$ pounds, which is actually a compressive stress.

To determine the value of P_0, which will bring the tensile stress at the inner surface up to 19,200 pounds, we have from Virgile

$$\theta_0=\frac{P_0(R_1^2+R_0^2)-2P_1R_1^2}{R_1^2-R_0^2}$$

from which making $P_1=P_1^1+lP_0$

$$P_0=\frac{(R_1^2-R_0^2)\,\theta_0+2P_1^1R_1^2}{(R_1^2+R_0^2)-2lR_1^2}=35944 \text{ pounds.}$$

The tangential extension at the bore produced by $P_0=24623$ is given by

$$\frac{\Delta R_0}{R_0}\varepsilon_0=t_0+\frac{P_0}{3}=7338 \text{ pounds.}$$

$$p_1=lP_0=2182 \text{ pounds.}$$

$$P_1=P_1^1+p_1=13902 \text{ pounds.}$$

Making, in E and F, $r=R_1$
we have

$$\frac{\Delta R_1}{R_1}=\frac{6P_0R_0^2-(4R_0^2+2R_1^2)P_1}{3(R_1^2-R_0^2)\varepsilon_0} \qquad \text{Q}$$

$$\frac{d\Delta R_1}{dR_1}=-\frac{2P_0R_0^2-(4R_0^2-2R_1^2)P_1}{3(R^2-R_0^2)\varepsilon_0} \qquad \text{R}$$

Substituting the proper values in these we find

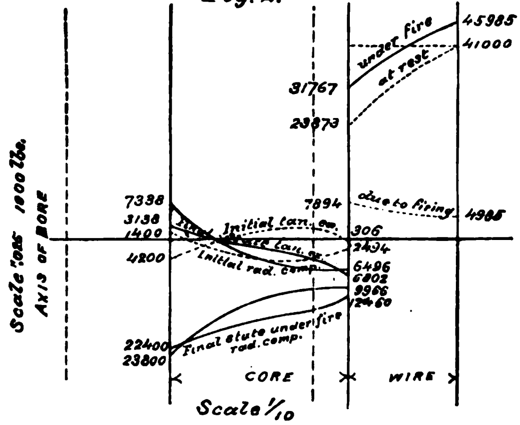
$$\frac{\Delta R_1}{R_1}\varepsilon_0=-6496 \text{ pounds.}$$

$$\frac{d\Delta R_1}{dR_1}\varepsilon_0=-7227 \text{ pounds.}$$

There are represented on the figure three sets of curves. The first set represent the radial and tangential strains, neglecting those due to

the initial strains in the casting. The second set, those due to the latter strains only (Report on trial cyl.), and the third set which are combinations of the first two

Fig. 2.



Scale ⅒

those due to both causes, or the final state of the core under fire. The method of constructing the curve of initial radial strain needs a word of explanation. The curve of initial tangential strain was obtained by experiment. Equations E and F show the curves of radial and tangential strains to be symmetrical with respect to a right line parallel to the axis r and distant from it

$$\frac{2(P_0R_0^2-P_1R_1^2)}{3(R_1^2-R_0^2)\,\varepsilon_0}$$

Equations H and K show that when $P_0 = o$ and $r = R_0$ the radial strain is of the opposite character from the tangential, and one-third of it in amount. By these two principles, the curve of tangential strains being given, that of radial strains is easily laid out.

STRAINS IN THE WIRE.

Resuming formula (B) and making in it $r = R_1$ we deduce for the strain of extension of the wire at the inner surface at rest,

$$\frac{\Delta\,R_1}{R_1}\,\varepsilon_1 = 23873 \text{ pounds.}$$

At the outer surface it is, of course, 41,000 pounds the tension of winding. Under fire $p_1=2{,}182$ pounds. Substituting in (E) the letters corresponding to the second or wire cylinders, then making $P_2=o$ and $r=R_1$ we have

$$\frac{\Delta R_1}{R_1}\varepsilon_1=\frac{(4R_2{}^2 2+R_1{}^2+)p_1}{3(R_2{}^2-R_1{}^2)}$$

from which

$$\frac{\Delta R_1}{R_1}\varepsilon_1(\text{due to } P_0)=7894 \text{ pounds}$$

similarly

$$\frac{\Delta R_2}{R_2}\varepsilon_1(\text{due to } P_0)=\frac{2R_1{}^2p_1}{R_2{}^2-R_1{}^2}=4985 \text{ pounds.}$$

The lines representing all these strains are shown on Fig. 2. The curve of extensions at rest, that produced from the increase of pressure from firing and finally the one whose ordinates are the sums of those of the first two, showing the state of extension of the wire under fire.

This completes the theoretical discussion of the tangential resistance of the section through the powder-chamber, under the supposition that the powder pressure shall not exceed 24,023 pounds.

But of course it is intended to subject the gun to much higher pressures than this; it would otherwise be of little use as a modern weapon, and we will determine the elastic strains of the core and coil under a powder pressure of 32,000 pounds per square inch, or what would be the strains if the elastic limit were not exceeded by this pressure.

$$p_1=2906 \text{ pounds.}$$

$$P_1=P_1{}^1+p_1=14626 \text{ pounds.}$$

$$\frac{\Delta R_0}{R_0}\varepsilon_0=\frac{(4\,R_1{}^2+2\,R_0{}^2)\,P_0-6\,R_1{}^2\,P_1}{3\,(R_1{}^2-R_0{}^2)}$$

$$=18757 \text{ pounds.}$$

$$\frac{\Delta R_1}{R_1}\varepsilon_0=-4407 \text{ pounds.}$$

$$\frac{d\,\Delta R_0}{d\,R_0}\varepsilon_0=-34696 \text{ pounds.}$$

$$\frac{d\,\Delta R_1}{d\,R_1}\varepsilon_0=-11532 \text{ pounds.}$$

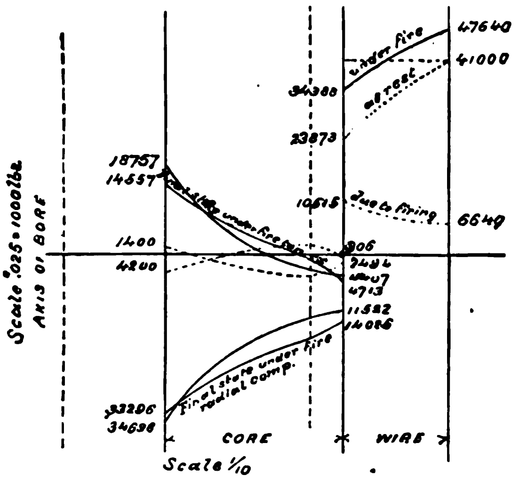
For the wire—

$$\frac{\Delta R_1}{R_1}\varepsilon_1\ (\text{due to } P_0)=10515 \text{ pounds.}$$

$$\frac{\Delta R_2}{R_2}\varepsilon_1\ (\text{due to } P_0)=6.640 \text{ pounds.}$$

All of which is represented graphically in Fig. 3.

Fig. 3.



THE SECTION IMMEDIATELY IN REAR OF THE TRUNNION-BAND.

It was desired to have the tangential compressive strain at the bore, due to the initial pressure, maintain as far forward as the front edge of the trunnion-band the value which it has in the powder-chamber.

With regard to the section immediately in rear of the trunnion-band, the new problem presented for solution is to determine the tension with which the wire in the depressed portion should be wound in order that the pressure, together with that of the wire wound over it at the tension of 41,000 pounds, should produce the tangential compression desired.

The section will be considered as composed of three rings, an inner one of cast-iron 8.96 inches thick, a middle one of steel .9 inch thick, and an outer one of steel 5.49 inches thick.

The required compressive strain at the bore is (Fig. 1) 27,046 pounds. The normal pressure on the core required to produce this is (Eq. H) 11,866 pounds.

The pressure produced by the wire of the exterior cylinder wound under a tension of 41,000 pounds upon the compound cylinder of steel and cast iron beneath it is (Eq. D)

$$P_2^1 = 11911 \text{ pounds.}$$

The transmitted pressure from this to the exterior surface of the core denoted by p_1^1 results from

$$p_1^1 = \frac{6 R_2^2 \varepsilon_0 (R_1^2 - R_0^2)}{\varepsilon_1 (R_2^2 - R_1^2)(4R_0^2 + 2R_1^2) + \varepsilon_0 (R_1^2 - R_0^2)(4R_2^2 + 2R_1^2)} P_2^1 \qquad \text{S.}$$

(Eq. 39*a*, note 35)

and is equal to 11395 pounds.

The pressure to be supplied by the inner wire cylinder, denoted by ψ_1^1 is then

$$\psi_1^1 = P_1^1 - p_1^1 = 171 \text{ pounds.}$$

The tension of winding required to produce this pressure is

(Eq. A) $$T_1 = 7715 \text{ pounds}$$

which represents 174 pounds on the wire.

The tangential compressive strain on the exterior of the core is

(Eq. Q) $$\frac{\Delta R_1}{R_1} \varepsilon_0 = -11403 \text{ pounds.}$$

The radial strains are

$$\frac{d \Delta R_0}{d R_0} = 9015 \text{ pounds.}$$

$$\frac{d \Delta R_1}{d R_1} = -6628 \text{ pounds.}$$

For the purpose of determining the strains due to firing it is simplest to consider the two wire cylinders, since they have the same modulus of elasticity, as one cylinder.

The formula for p_1 then becomes

$$p_1 = \frac{6R_0^2 \varepsilon_1 (R_3^2 - R_1^2)}{\varepsilon_1 (R_3^2 - R_1^2)(4R_0^2 + 2R_1^2) + \varepsilon_0 (R_1^2 - R_0^2)(4R_3^2 + 2R_1^2)} P_0$$

$$= l P_0$$

$$l = (2.9866612)$$

From (O) and (P) with values 19200 and 23800 for θ_0 and ρ_0

$$P_0^{(1)} = 33039 \text{ pounds.}$$

$$P_0^{(2)} = 24220 \text{ pounds.}$$

THE SECTION UNDER THE TRUNNION-BAND.

For the purpose of determining the shrinkage of the trunnion-band this section will be considered as composed of four concentric rings, whose radii are given in Table 1.

The pressure at the exterior surface of the core produced by the tension of the inner wire cylinder is (p. 39) 471 pounds. That produced at the exterior surface of the inner wire cylinder by the tension of the outer wire cylinder wound under 41,000 pounds is (Eq. D) 7032 pounds, and of this there is transmitted to the surface of the core (Eq. S) 6727 pounds, so that the pressure on the core produced by both the wire cylinders is 471+6727=7198 pounds.

As before stated the pressure on the core to produce the desired compression at the bore must be 11,866 pounds, leaving 11866−7198=4668 pounds to be supplied by the trunnion-band. The pressure of the trunnion-band on the exterior of the wire which will transmit this pressure to the core is obtained from (Eq. S) (considering now the wire as 1 cylinder) which becomes

$$p_1{}^1=\frac{6R_3{}^2\,\varepsilon_0\,(R_1{}^2-R_0{}^2)}{\varepsilon_1\,(R_3{}^2-R_1{}^2)\,(4R_0{}^2+2R_1{}^2)+\varepsilon_0\,(R_1{}^2+R_0{}^2)\,(4R_3{}^2+2R_1{}^2)}\,P_3{}^1 \qquad \text{T}$$

and is found to be

$$P_3{}^1=5388 \text{ pounds.}$$

The shrinkage required to produce this pressure is given by the formula (adapted from the second of Eqs. 44′, note 35)

$$\varphi_3=\frac{(4R_1{}^2+2R_3{}^2)\,P_3{}^1-6R_1{}^2p_1{}^1}{3(R_3{}^2-R_1{}^2)\varepsilon_1}+\frac{(4R_4{}^2+2R_3{}^2)P_3{}^1}{3(R_4{}^2-R_3{}^2)\varepsilon_3} \qquad \text{U}$$

solving which

$$\varphi_3=''.00021361+''.00080725=''.00102086.$$

$$\varphi_3\times D_3=''.03675 \text{ taken as } ''.037.$$

The actual shrinkage corresponded almost exactly with the theoretical.

The diameter assumed by the wound wire required the turned diameter to be 35″.87, and the bored one to be 35.″833. The state of the core at rest is of course the same as in the preceding section. Resuming Eq. L. $p_1=lP_0$

The value of 1 is found from

$$\left.\begin{aligned} p_3&=\frac{6R_1{}^2\,\varepsilon_3\,(R_4{}^2-R_3{}^2)}{\varepsilon^3\,(R_4{}^2-R_3{}^2)\,(4R_1{}^2+2R_3{}^2)+\varepsilon_1\,(R_3{}^2-R^2{}_1)\,(4R_4{}^2+2R_3{}^2)}p_1\\ p_1&=\frac{6R_0{}^2\,\varepsilon_1\,(R_3{}^2-R_1{}^2)}{\varepsilon_1(R_3{}^2-R_1{}^2)\,(4R_0{}^2+2R_1{}^2)+\varepsilon_0\,(R_1{}^2-R_0{}^2)\,[(4R_3{}^2+2R_1{}^2)-6R_3{}^2t]}\,P_0\end{aligned}\right\}\text{V}$$

adapted from the set applicable to three cylinders of Eq. 33, note 35, t being the coefficient of p_1 in first equation.

$$p_3=(\bar{1}.5916184)p_1$$

$$p_1=(\bar{1}.0613067)P_0$$

$$l=(\bar{1}.0613067)$$

From equations O and P we have

$$P_0{}^{(1)}=34050 \text{ pounds.}$$

$$P_0{}^{(2)}=24472 \text{ pounds.}$$

SECTION UNDER SLEEVE.

The compression of the bore under the sleeve was designed to be three-quarters of that in the preceding portions, or 20,284 pounds.

This compression being proportional to the exterior pressure required for the latter, a value equal to three-fourths of 11,866, or 8,899 pounds. Of this, as seen before, 7,198 is supplied by the wire, leaving 1,701 pounds to be transmitted from the sleeve. The pressure of the sleeve on the wire should then be (Eq. T)

$$P_3^1 = 1963 \text{ pounds.}$$

The shrinkage of the sleeve to produce this pressure is (Eq. U)

$$\varphi_3 = ''.00007783 + ''.00076479 = ''.00084262$$

$$\varphi_3 \times D_3 = ''.030$$

The actual shrinkage did not correspond exactly with this theoretical, but was .0228 inch, equal to .0006 per inch of diameter. The pressure being proportional to the shrinkage, P_3^1 becomes 17,602 pounds. The transmitted pressure being proportional to this becomes 1,525 pounds, making P_1^1 8723 pounds and $\frac{\Delta R_0}{R_0}\varepsilon_0$—19883.

From Eqs. V we obtain

$$p_3 = (\bar{1}.2964446)p_1$$

$$p_1 = (\bar{2}.9636570)P_0$$

Whence

$$P_0^{(1)} = 27681 \text{ pounds.}$$
$$P_0^2 = 22387 \text{ pounds.}$$

Section under thick part of Ring F.

The tangential compression of the bore of this section was designed to be $\frac{3}{4}$ of 20,284 pounds, or practically 15,000 pounds.

For this compression (Eq. E)

$$P_1^1 = 6716$$

and for this pressure (Eq. 44, Note 35)

$$\varphi_1 = \frac{(4R_0^2 + 2R_1^2)P_1^1}{3(R_1^2 - R_0^2)\varepsilon_0} + \frac{(4R_2^2 + 2R_1^2)P_1^1}{3(R_2^2 - R_1^2)\varepsilon_1} \quad . \quad . \quad \text{W.}$$

$$= ''.00033575 + ''.00091239 = .00124814$$
$$\varphi_1 \times D_1 = ''.03863 \text{ taken as } ''.039.$$

The actual shrinkage was

$$\varphi_1 = .00148$$

making the actual value of P_1^1 7965 pounds and of

$$\frac{\Delta R_0}{R_0}\varepsilon_0 \text{—17787 pounds.}$$

From Eq. E

$$l=(\bar{2}.7667198)$$

From O and P

$$P_0^{(1)}=25758 \text{ pounds.}$$
$$P_0^{(2)}=21738 \text{ pounds.}$$

Section under thin part of Ring F.

The shrinkage having been fixed above, the pressure results from it. Solving (W)

$$P_1{}^1=\frac{\varphi}{\frac{4R_0^2+2R_1^2}{3(R_1^2-R_0^2)\varepsilon^2}+\frac{4R_2^2+2R_1^2}{3(R_2^2-R_1^2)\varepsilon_1}} \quad . \quad . \quad \text{X.}$$

Substituting in this the actual value of φ.

$$P_1{}^1=5926 \text{ pounds.}$$

and

$$\frac{\Delta R_0}{R_0}\varepsilon_0=13234 \text{ pounds.}$$
$$p_1=(\bar{2}.7148619)\ P_0$$
$$P_0^{(1)}=22399 \text{ pounds.}$$
$$P_0^{(2)}=20555 \text{ pounds.}$$

SECTION UNDER RING G.

There is no initial pressure by this ring, and the contact is considered absolute.

$$p_1=(\bar{2}.9547619)\ P_0$$
$$P_0^{(1)}=13685 \text{ pounds.}$$
$$P_0^{(2)}=17545 \text{ pounds.}$$

SECTION IN FRONT OF RING G.

For P_0 (Eq. 17, Note 35)

$$P_0^{(1)}=\frac{3(R_1^2-R_0^2)\theta_0}{4R_1^2+2R_0} \qquad \text{Y.}$$
$$P_0=11941 \text{ pounds.}$$

SECTION AT MUZZLE.

From equation Y

$$P_0=9144 \text{ pounds.}$$

SECTION OF BREECH-BLOCK RECESS UNDER WIRE.

Eq. (A) gives $P_1{}^1=11310$ pounds, and Eq. (E)

$$\frac{\Delta R_0}{R_0}\varepsilon_0=-28566 \text{ pounds.}$$

Eq. F. $$\frac{d\,\Delta R_0}{dR_0}\varepsilon_0=+9522 \text{ pounds.}$$

SECTION OF BREECH-LOCK RECESS UNDER RING A.

The design was to have the tangential compression of the bore three-quarters of its value under the wire, or 21,423 pounds. The exterior pressure required was $P_1{}^1=8482$ pounds.

By an exactly similar process to that pursued with ring F, φ_1 is found to be ".00157, and $\varphi_1 \times D_1=$".04586.

The actual value of φ_1 was ".00165, making $P_1{}^1=8910$, and

$$\frac{\Delta R_0}{R_0}\varepsilon_0=22683 \text{ pounds.}$$

THE LONGITUDINAL STRENGTH.

The longitudinal strain is greatest in the section through the rear end of the powder chamber, at which section its value is given by Eq. G.

Substituting in that equation for P_0 32000, and for P_1 14626

$$\frac{d\,\Delta h}{dh}\varepsilon_0=7969 \text{ pounds,}$$

which is well within the elastic limit of the cast iron.

The line of compression of the bore at rest, due to the external pressure; that due to both the external pressure and the initial strain of the casting, and that showing the elastic strength of the gun at the different sections are shown in Plate III. The initial strain, shown by experiments to exist in the powder chamber, is supposed to extend to the muzzle.

In order to complete this part of the subject there remain to be shown the curve of velocities of the projectile in the bore of the gun, the curve of powder pressure, and the strains in the different cylinders under these pressures. These are reserved, awaiting the completion of the gun and the acquisition of more definite information in regard to the kind of powder to be used and the weight of projectile and charge.

PART V.

THE PRACTICAL OPERATIONS.

The gun and forgings, with the exception of rings A, F, and G, were received on November 10, 1884; rings A and F on February 12, 1885, and ring G on June 1, 1886. The first invoice of wire was received June 27, 1885. The time between that date and November 1 was occupied with the winding machine and trial cylinder.

Putting the gun in the lathe was commenced on November 10, 1885, which should be taken as the date upon which work upon the gun proper

was commenced, although previously to that date the following small parts had been prepared: The rounded filling rings were finished on May 5, 1885; the spool rings B and E on May 15, 1885.

Work on the other rings and on the breech mechanism proceeded concurrently with that on the gun proper.

On November 30, 1885, was commenced the work of finishing the gun for the application of the wire, and cutting the thread for the spool ring B. This thread was cut by means of a screw-bonnet clamped on the gun, the thread on which bonnet had been cut on the lathe upon which the spool ring had been threaded. A bar carrying upon one end a partial nut fitting the thread of the screw-bonnet and upon the other the cutting tool, insured the exact reproduction of the thread of the screw-bonnet upon the gun.

This work was completed on January 7, 1886.

WINDING.

The fitting up of the winding machine, reels, &c., was completed on January 16, on which date the winding began.

The wire was fastened at the starting end by drilling a radial hole in the cast-iron body, the diameter of the hole being slightly less than the diagonal of the section of the wire, then bending the annealed wire and driving the end of it into the hole. The winding was commenced at the front end of the depressed portion and was continuous throughout.

The tension in the depressed portion being only 7,715 pounds, the action of the machine was more satisfactory and the winding progressed with more rapidity than in the other portions.

When a break occurred or the end of a coil was reached, the wire was spliced by scarfing the ends with a file for a length of about 2 inches, laying a strip of silver solder in the joint, and clasping with a heavy pair of heated tongs. The solder melted and brazed the wire together. In splicing pieces for filling the reels, the scarfed surfaces were toothed before being brazed together. After brazing the joint was swaged by hammering.

Whether the toothing added to the strength of the joint is not definitely known; it is presumed that it did. The heating of the wire so annealed it that its strength was reduced to about 75,000 pounds per square inch. Various measures were tried to increase the strength of the splice, but none were successful. It is, however, ample for this gun.

The winding up to the diameter for the reception of the trunnion band and sleeve was completed on March 18, 1886. The loose ends of the wire were secured by solder and in addition the clamp ring was set on tightly, to prevent loss of tension while moving the gun about.

PREPARING THE SURFACES FOR SHRINKAGE.

The turning of the seat for the trunnion band and sleeve required the removal of about .05 of an inch on a side from the outside of the wire, or about one-third of its section. This was done without difficulty, leaving a good surface for shrinking.

For turning the adjacent surface for the reception of ring F, the turned surface of the wire was used as a bearing surface upon which to revolve the gun. Some apprehension was felt as to the effect of this upon the wire, and the layers were soldered together beyond the turned portion to prevent them from unwinding in the event of a break. None, however, occurred.

The gun was ready for the rings on April 28, 1886.

SHRINKING.

For putting on ring A the gun was placed with the breech toward the furnace.

The shrinking on of this ring was quite satisfactory, except in the matter of time required to heat it up. The draught-pipe of the furnace was too small, and was afterwards increased with good effect.

The increase of the diameter of the ring was made up of the shrinkage plus the taper plus the clearance. The last was .02 of an inch, and the sum of all was .1184 of an inch, or .0041 of an inch per inch of diameter, requiring a temperature of nearly 700 degrees Fahrenheit. This is a more than ordinarily high expansion.

The joint between rings A and B is, as far as can be seen, perfect. Below is a record of time required.

Time record of shrinking.

Ring A.	P. M. h.	m.	s.
Hoop adjusted in heating chamber	15	25	10
Furnace opened	4	58	4
Time in heating	4	32	54
Color of hoop, blue	.....		.....
Hoop in position	4	59	50
Time required to get hoop on		1	46
Water ring in position	5	2	30
Time from getting hoop in place to turning on water		2	40
Time water running		43	45
Pressure removed, next day	......		.....

This ring was put on on May 8, 1886.

The gun was then reversed and preparations made for placing the trunnion ring. For this ring the press was not required. A small ring was clamped on the gun for the trunnion ring to bring up against, and it was allowed to cool in its place. The water was thrown by the water ring against the rear face of the trunnion ring.

The rising of the ring after a short time from the gun at the front end showed that it had clamped the gun at the rear.

On account of the weight of the trunnion ring, the distance necessary to carry it while hot, and the improvised nature of the appliances for placing it, together with consideration of the fact of its subsidiary office in resistance, it was considered advisable to give it quite a large clearance. This the small value of the shrinkage permitted to be done without overheating the metal. The clearance over the largest diameter of the seat was .084 inch. The expansion was .126 inch, or .0035 per inch of diameter.

Time record of shrinking.—Trunnion Ring C.

Subject of observation.	A. M. h.	m.	s.
Hoop adjusted in heating chamber	7	59	0
Furnace opened	11	45	0
Time in heating	3	46	0
Hoop in position	11	48	45
Time required to get hoop on		3	45
Water turned on	11	50	20
Water turned off, 2 p. m	....		

The smallest clearance of the sleeve was .07 of an inch. This required an expansion of .096 of an inch, equal to .0026 of an inch per inch of diameter.

The sleeve was placed without difficulty. Its length and that of the trunnion ring were so arranged that the front face of the ring should project about .01 of an inch beyond Ring E, to insure that Ring F should bear against the sleeve and not against the spool ring. The press worked satisfactorily and the joint between the sleeve and the trunnion ring appears to be perfect.

Time record of shrinking.—Sleeve ring D.

Subject of observation.	P. M.		
	h.	*m.*	*s.*
Hoop adjusted in heating chamber	12	0	0
Furnace opened	2	46	58
Time in heating	2	46	58
Color of hoop, blue	..	..	..
Hoop in position	2	49	10
Time required to get hoop on		2	12
Pressure bolts applied	2	50	20
Time required to get press in action		1	10
Water turned on	2	53	0
Water turned off	3	21	0
Hoop cool	3	41	30
Time from getting hoop in place to turning on water		3	50
Time water running		28	0
Time in cooling		48	30
Gas ring in position and gas lighted	2	51	0
Gas ring removed	3	7	10
Time of using gas ring		16	10
Pressure removed	4	7	0

It will be observed that the water was not turned on until after the gas ring was in operation. The gas ring is of doubtful necessity. It was used in this instance on account of the length of the sleeve.

The clearance of Ring F was .0584 of an inch; the expansion .1085 of an inch, equal to .0035 of an inch per inch of diameter. The operation of putting it on was performed with success except in the application of the press bolts. The machinist superintending the placing of the bolts upon the left side of the gun, an intelligent man, the one who had made and marked the gauges for setting the nuts, became excited, snapped both gauges from their rods, got them interchanged in his hands and applied them wrongly. In a moment they were tightened by the shrinking of the rods, and it was impossible to move them. The strain upon one rod, was thus made very much too great and that upon the other too little. The heavily strained one, as it continued to cool, broke off the corner of the casting in which it was pivoted and fell down.

The press thus left acting on one side only naturally failed to do its work, and the joint was left open .003 of an inch on one side and .008 of an inch on the other. This it is intended to close up.

The water ring was used to cool off the rear edge of the ring.

In spite of the mishap the joint is a fairly good one.

Time record of shrinking.—Ring F.

Subject of observation.	P. M.		
	h.	*m.*	*s.*
Hoop adjusted in heating chamber	1	0	15
Furnace opened	4	23	35
Time in heating	3	23	20
Hoop in position	4	25	30
Pressure bolts applied	4	26	55
Water turned on	4	30	20
Time water running	1	30	0

N. W. nut set up too far by .25 of an inch.
S. W. nut set up too little by .125 of an inch.

The shrinking of the hoops was finished on May 10, 1886.

While the gun was out of the lathe the head-stock of the latter was raised so as to permit the gun with the trunnion ring upon it to revolve clear of the base of the winding machine or the traveling carriage.

The gun was replaced in the lathe on May 29, and, pending the completion of a gear, made necessary by the raising of the head-stock, work was done in turning off the outside of the rings.

The winding was recommenced on June 10, and continued until July 1, when failure of appropriation for the continuance of the work necessitated its suspension.

There remain to be applied four layers of wire. After which the gun is to be finished on the outside, bored and rifled, and the recess for the breech-block threaded.

The following is a list of the principal appliances made for use in the manufacture of this gun.

Gears, &c., for gearing up large lathe.
Winding machine.
Back-rest for 48-inch lathe.
Boring and rifling attachment to large lathe.
Shafting in winding shop.
Shafting for 48-inch lathe.
Three screw-bonnets.
Gun bearings for large lathe.
Muzzle-driving chuck for large lathe.
Reels for carrying wire.
Truck for carrying reels.
Chuck for holding rings in 48-inch lathe.
Independent carriage for large lathe, for use with screw-bonnets.
Revolving apparatus for soldering furnace. (Partly finished).
Pieces for raising head-stock of 48-inch lathe.
Pieces for raising head-stock of large lathe.
Breech-driving chuck for large lathe.
Back-rest for large lathe
Overhead crane for soldering furnace.
Tapering machine for wires.
Splicing machine for wires.

The list comprises only the larger articles.

I am, sir, very respectfully, your obedient servant,

WILLIAM CROZIER,
First Lieutenant of Ordnance.

APPENDIX A.

[Tinned steel wire, mark 5; sectional area 0''.147x=0''.147=0''.016.]

Applied loads per square inch.	Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Pounds.					
5,000	0	0	....	....	Initial load.
10,000	.000190	.190	....	....	
15,000	.000380	.000190	....	....	
20,000	.000560	.000200	....	....	
25,000	.000760	.000180	....	....	
30,000	.000930	.000170	....	....	
35,000	.001120	.000190	....	....	
40,000	.001320	.000200	.000010	.000010	
45,000	.001520	.000200	....	....	
50,000	.001710	.000190	....	....	
55,000	.001910	.000200	....	....	
60,000	.002120	.000210	.000080	.000070	
65,000	.002330	.000210	....	....	
70,000	.002550	.000220	....	....	
75,000	.002780	.000230	....	....	
80,000	.003000	.000220	.000200	.000120	
85,000	.003220	.000220	....	....	
90,000	.003470	.000250	....	....	
95,000	.003700	.000230	....	....	
100,000	.003970	.000270	.000480	.000280	
105,000	.004260	.000290	....	....	
110,000	.004510	.000250	....	....	
115,000	.004820	.000310	....	....	
120,000	.005150	.000330	.000810	.000330	
125,000	.005510	.000360	....	....	
130,000	.005830	.000320	....	....	
135,000	.006230	.000400	....	....	
140,000	.006840	.000610	.001540	.000730	
145,000	.007300	.000460	....	....	
150,000	.007970	.000670	....	....	
155,000	.0085	.000530	....	....	
160,000	.0095	.0010	....	....	
165,000	.0110	.0015	....	....	
170,000	.0130	.0020	....	....	
175,000	.0160	.0030	....	....	
178,240	.0290	.0130	....	....	Tensile strength.

APPENDIX B.

[Cast iron from breech disc of 10-inch wire-wrapped rifle; tangential extension, inside specimen: mark 4, diameter 1.129; sectional area, 1 square inch; gauged length, 20 inches.]

Applied loads per square inch.	Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Pounds.					
500	0	0	0	0	Initial load.
1,000	.000015	.000015	0	....	
2,000	.000060	.000045	0	....	
3,000	.0000110	.000050	0	....	
4,000	.000160	.000050	0	....	
5,000	.000220	.000060	.000005	.000005	
6,000	.000260	.000040	.000010	.000005	
7,000	.000310	.000050	.000010	0	
8,000	.000360	.000050	.000010	0	
9,000	.000425	.000060	.000025	.000015	
10,000	.000490	.000070	.000040	.000015	
11,000	.000545	.000055	.000045	.000005	
12,000	.000610	.000065	.000045	0	
13,000	.000650	.000040	.000055	.000010	
14,000	.000720	.000070	.000060	.000005	
15,000	.000795	.000075	.000065	.000005	Elastic limit.
16,000	.000870	.000075	.000090	.000035	
17,000	.000945	.000075	.000100	.000010	
18,000	.001035	.000090	.000135	.000035	
19,000	.001125	.000090	.000150	.000015	
20,000	.001225	.000100	.000190	.000040	
21,000	.001320	.000095	.000220	.000030	
22,000	.001445	.000125	.000270	.000050	
23,000	.001555	.000110	.000320	.000050	
24,000	.001710	.000155	.000390	.000070	
25,000	.001880	.000170	.000490	.000100	
26,000	.002015	.000135	.000550	.000060	
27,000	.002250	.000235	.000605	.000145	
28,000	.002540	.000290	.000900	.000205	
29,000	.002900	.000360	.001185	.000285	
29,120	....	....	....	....	Tensile strength.

APPENDIX C.

[C iron frustom breech disc of 10-inch wire-wound rifle; tangential compression, inside specimen; mark, 7; length, 12 inches; diameter, 1.129 inch; sectional area, 1 square inch.]

Applied loads per square inch.	Compression per inch.	Successive compression per inch.	Permanent set.	Successive permanent set.	Remarks.
Pounds.					
500	....	....	....	....	Initial load.
1,000	.000030	.000030	....	....	
2,000	.000090	.000060	....	....	
3,000	.000130	.000040	....	....	
4,000	.000190	.000060	....	....	
5,000	.000230	.000040	....	....	
6,000	.000290	.000060	....	....	
7,000	.000330	.000040	....	....	
8,000	.000390	.000060	.000030	....	
9,000	.000430	.000040	.000030	....	
10,000	.000500	.000070	.000040	....	
11,000	.000550	.000050	.000050	....	
12,000	.000600	.000050	.000070	....	
13,000	.000680	.000080	.000080	.000010	
14,000	.000710	.000030	.000090	.000010	
15,000	.000770	.000060	.000100	.000010	
16,000	.000840	.000070	.000100	0	
17,000	.000900	.000060	.000100	0	
18,000	.000980	.000080	.000110	.000010	
19,000	.001040	.000060	.000120	.000010	
20,000	.001100	.000060	.000130	.000010	
21,000	.001180	.000080	.000150	.000020	
22,000	.001240	.000060	.000180	.000030	
23,000	.001320	.000080	.000190	.000010	
24,000	.001390	.000070	.000200	.000010	
25,000	.001480	.000090	.000240	.000040	Perceptible deflection.
26,000	.001570	.000090	.000290	.000050	
27,000	.001650	.000080	.000310	.000020	
28,000	.001750	.000100	.000380	.000070	
29,000	.001860	.000110	.000410	.000030	
30,000	.001970	.000110	.000490	.000080	
31,000	.002110	.000140	.000580	.000090	
32,000	.002290	.000180	.000680	.000100	
33,000	.002440	.000150	.000790	.000110	
34,000	.002640	.000200	.000930	.000140	
35,000	.002930	.000290	.001150	.000220	
36,000	.003130	.000200	.001330	.000180	
37,000	.003460	.000330	.001300	.000270	
38,000	.003780	.000320	.001800	.000260	
39,000	.004150	.000370	.002180	.000320	
40,000	.004540	.000390	.002530	.000350	
52,000	....	....	....	....	Ultimate strength.

[Cast iron from breech disc of 10-inch wire-wound rifle; radial compression; mark, 10; length 11.65 inches; diameter 1.129 inch; sectional area 1 square inch.]

Applied loads per square inch.	Compression per inch.	Successive compression per inch.	Permanent set.	Successive permanent set.	Remarks.
Pounds.					
500	0	0	0	....	Initial load.
1,000	.000018	.000018	....	....	
2,000	.000036	.000018	....	....	
3,000	.000072	.000036	....	....	
4,000	.000109	.000037	....	....	
5,000	.000164	.000055	....	....	
6,000	.000217	.000053	....	....	
7,000	.000273	.000056	....	....	
8,000	.000309	.000036	....	....	
9,000	.000345	.000036	....	....	
10,000	.000381	.000036	.000018	.000018	
11,000	.000453	.000072	.000018	0	
12,000	.000489	.000036	.000036	.000018	
13,000	.000525	.000036	.000036	.000018	
14,000	.000561	.000036	.000036	.000018	
15,000	.000670	.000109	.000054	.000018	
16,000	.000688	.000018	.000054	0	
17,000	.000746	.000058	.000072	.000018	
18,000	.000800	.000054	.000091	.000019	
19,000	.000855	.000055	.000109	.000018	
20,000	.000891	.000036	.000127	.000018	
21,000	.000963	.000072	.000127	0	
22,000	.001035	.000072	.000127	0	
23,000	.001071	.000036	.000127	0	
24,000	.001143	.000072	.000145	.000018	
25,000	.001215	.000072	.000145	0	
26,000	.001287	.000072	.000163	.000018	
27,000	.001359	.000072	.000181	.000018	
28,000	.001431	.000072	.000217	.000036	
29,000	.001467	.000036	.000235	.000018	
30,000	.001594	.000127	.000253	.000018	Perceptible deflection.
31,000	.001727	.000133	.000307	.000054	
32,000	.001799	.000072	.000343	.000036	
33,000	.001891	.000092	.000415	.000072	
34,000	.001981	.000090	.000469	.000054	
35,000	.002127	.000146	.000541	.000072	
36,000	.002345	.000218	.000670	.000129	
37,000	.002490	.000145	.000779	.000109	
38,000	.002672	.000182	.000906	.000127	
39,000	.003000	.000328	.001143	.000237	
40,000	.003290	.000290	.001359	.000216	
61,900	....	....	....	....	Ultimate strength.

NOTE BY W. E. WOODBRIDGE.

It may be said of the machine referred to that by its means the wire was applied with "quite sufficient accuracy of tension" (as stated in the report), that it was easily operated by one person, that the tension could be easily regulated and varied at will by the operator without interrupting the course of winding, and that it suffered no visible deterioration by use.

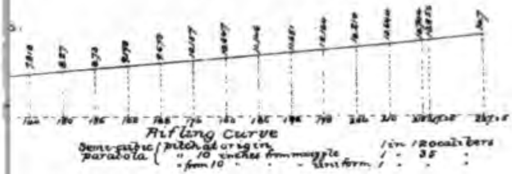
As to the rate of winding in actual operating time, it has served to lay 90 pounds of wire per hour, including in that time a proportional part of the time required for resupplying the papers surrounding the "discs."

During the winding of the gun, an observation extending through nearly four days (of eight hours work) showed that, including the supply of new reels of wire, the joining of the wires of the reels to those previously wound, the insertion of the filling-pieces at the ends of each layer, the special clamping and covering at night, the uncovering and making ready in the morning, and every operation and delay attendant upon laying the wire, the rate was 45¼ pounds per hour. Nothing but an increase of speed of rotation of the gun in the winding lathe is necessary to increase the rate of winding to a limit not yet known.

There is no reason why the operation could not be continued with advantage through the twenty-four hours of each day if desired, and the result would be, at 45 pounds per hour, the winding of more than 1,000 pounds per day.

It would seem that the quality and rate of work above stated, and the machinery by which it is accomplished, might be considered satisfactory until something better can be shown.

PLATE I.



Locking Ring

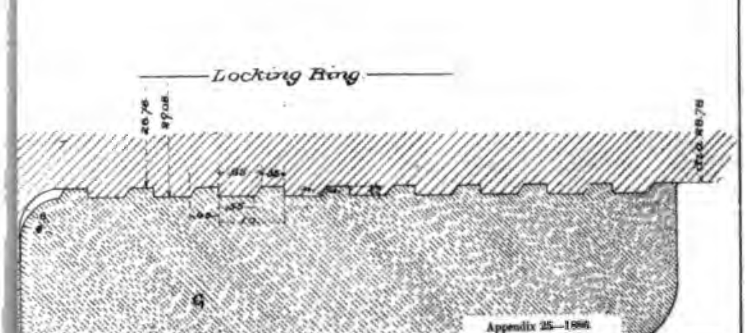
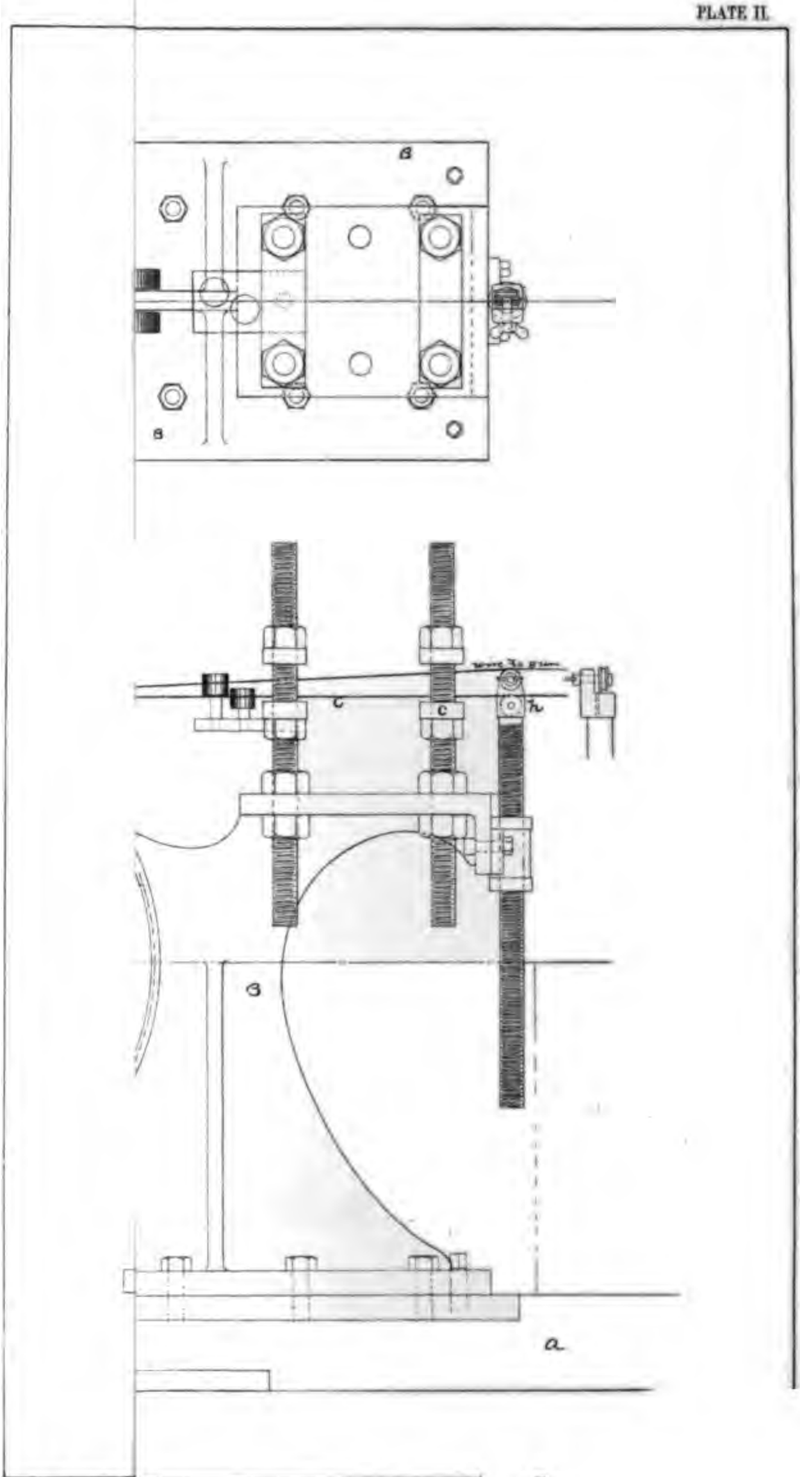


PLATE II.



H Ex1 pt2

APPENDIX 26.

REPORT OF EXPERIMENTS MADE AT THE WEST POINT FOUNDRY TO TEST THE QUALITIES OF A FORGED, OIL-TEMPERED, AND ANNEALED MIDVALE STEEL TRUNNION-HOOP WHEN APPLIED UNDER SHRINKAGE TO A CAST-IRON BODY.

By CAPT. ROGERS BIRNIE, JR., ORDNANCE DEPARTMENT.

(2 Plates.)

[Trunnion-hoop for 8-inch steel breech-loading rifle, designated 8 THEX.—1885.]

This hoop was ordered by Chief of Ordnance, U. S. Army, for experimental purposes, to test the qualities of forged steel trunnion-hoops. It was made by the Midvale Steel Company in the year 1885. Its manufacture has been described by Lieut. F. E. Hobbs, Ordnance Department, U. S. Army, Inspector at the Steel Works.*

In the design of gun presented the trunnion-hoop is assembled under shrinkage and must aid in the tangential resistance of the gun besides forming the support of the trunnions, and for this purpose, in the present state of the art, a cast-steel trunnion-hoop can scarcely be considered adequate.

The hoop was subjected to two distinct series of mechanical tests, comprising, first, tensile tests of eighteen specimens taken from the two ends and the central portion of the hoop, and, second, shrinkage tests of one-half of the hoop.

The rough-finished hoop, of which the dimensions are given, Plate I, weighed 2,568 pounds when received at the West Point Foundry.

TENSILE TESTS.

In Plate I the hoop is shown divided into the parts A, B, C, as it was cut to take out the central specimen ring "C." The specimens from this ring, Nos. 9 to 18, inclusive, were prepared at the West Point Foundry; specimens 1 to 8 had previously been taken under direction of Lieut. F. E. Hobbs, U. S. Ordnance Department, at the Midvale Steel Works—Nos. 1 to 4 from the end marked A, and 5 to 8 from the end marked B; Nos. 1 and 5, 2 and 6, 3 and 7, and 4 and 8 were taken, two and two, from the ends of the hoop opposite each other.

All of the specimens were tested upon the machine at Watertown Arsenal, Massachusetts. The following table presents a summary of the records grouped for the parts of the hoop, and the general mean.†

* See Appendix II.

† The records of tests for the 18 specimens will be printed in full in the forthcoming report, "Tests of Metals, &c., 1886."

Mean results of tests, by tension, of 18 round bars taken from forged, oil-tempered, and annealed Midvale (experimental) steel trunnion-hoop for 8-inch steel breech-loading rifle.

[Tangential specimens 6.0 inches in length and 0.25 square inch cross-section.]

Load per square inch of cross-section.	Relative elongations. End A. Specimen 1-4.	Center C. Specimens 9-18.	End B. Specimens 5-8.	General mean.
Pounds.	*Thousandths.*	*Thousandths.*	*Thousandths.*	*Thousandths.*
10,000	0.312	0.260	0.292	0.279
15,000	0.475	0.433	0.446	0.445
20,000	0.638	0.603	0.621	0.615
25,000	0.808	0.768	0.779	[illegible]
30,000	0.971	0.936	0.954	[illegible]
35,000	1.133	1.106	1.121	1.117
40,000	1.304	1.288	1.296	[illegible]
45,000	1.458	1.479	3.512	[illegible]
46,000	1.478	2.611	3.746	[illegible]
47,000	1.511	3.225	6.475	[illegible]
48,000	1.544	4.211	6.950	[illegible]
49,000	1.584	5.301	9.333	[illegible]
50,000	2.229	6.428	10.767	6.141
54,000	3.896	11.566	13.918	[illegible]
60,000	13.092	18.086	19.767	17.[illegible]
70,000	24.107	32.246	32.579	[illegible]
80,000	31.467	62.000	58.650	[illegible]
Adopted working limit of the metal: pounds[a]				45,0[illegible]
Adopted working limit of the metal: tons				[illegible]
Corresponding elongation, thousandths				1.[illegible]
Corresponding coefficient of elasticity: pounds				30,444,[illegible]
Corresponding coefficient of elasticity: tons				13,[illegible]
Elastic limit, pounds per square inch: minimum	49,000	45,000	44,000	44,[illegible]
Elastic limit, pounds per square inch: maximum	57,000	56,000	48,000	57,[illegible]
Elastic limit, pounds per square inch: average	53,750	48,300	46,250	[illegible],055
Corresponding elongations or compressions, thousandths: minimum	1.567	1.433	1.567	1.[illegible]
Corresponding elongations or compressions, thousandths: maximum	1.950	1.900	1.583	1.[illegible]
Corresponding elongations or compressions, thousandths: average	1.783	1.623	1.571	1.[illegible]
Resistance at failure on primitive section, pounds per sq. inch: minimum	89,600	80,760	87,000	[illegible],760
Resistance at failure on primitive section, pounds per sq. inch: maximum	93,920	91,960	89,000	[illegible]
Resistance at failure on primitive section, pounds per sq. inch: average	91,890	86,652	88,000	[illegible],135
Elongation per inch after rupture, per cent: minimum	17.67	16.50	14.50	14.[illegible]
Elongation per inch after rupture, per cent: maximum	22.17	19.33	20.30	22.17
Elongation per inch after rupture, per cent: average	19.25	17.81	18.04	18.18
Reduction of area after rupture, per cent. of primitive section: minimum	36.40	30.60	38.40	[illegible]
Reduction of area after rupture, per cent. of primitive section: maximum	54.60	59.30	52.20	[illegible]
Reduction of area after rupture, per cent. of primitive section: average	47.60	48.35	45.75	47.[illegible]
Specific gravity	7.8501			
Hardness	16.56			

A careful examination of the tests leads to the adoption of the values given in the column of general mean above for the elastic working limit of the metal, which it would not be safe to exceed in practice.

It is to be remarked that the mean of the group from the end A gave considerably higher values for the physical properties than either of the two others, whilst between those two there is a slight difference in favor of the central group, only, however, as regards elastic properties. The superiority of the end A was not confirmed by the shrinkage tests, and it is considered probable that the effect was local.

As regards the position of specimens, whether from the outside (see Nos. 9, 12, 13, 16, and 17, Plate I), middle (see Nos. 1 to 8 and 11 and 15), or inside (see Nos. 10, 14, and 18), or whether near or remote from the trunnion masses, no uniform law can be stated; but in each group the specimens giving the highest elastic properties (see Nos. 2, 4, 6, 8, 13, and 14) were taken within the trunnion masses and perpendicular to the axis of the trunnions. In the fracture, however, these specimens were partly granular, and three of them, Nos. 13, 2, and 6, gave the least "reduction of area after rupture" of the whole number tested, and their ultimate elongation also was relatively low. These indica-

tions help to explain the inferiority of the trunnion portions to the remainder of the hoop, subsequently developed in the shrinkage tests.

Considering the thoroughness of these tests and the average results—from which we find approximately the following: Elastic limit, 49,000 pounds; resistance at rupture, 88,000 pounds, and elongation at rupture (for 6-inch specimens) 18 per cent.—the good quality of the metal for this class of hoop is apparent.

SHRINKAGE TESTS.

These tests were conducted with the half of the hoop marked A, Plate I, and comprised, first, the elastic test; second, the strength test (so called), in which the hoop, having been carefully bored, faced, and turned, was heated and shrunk successively upon cast-iron cylinders. The object of the first was to determine whether the fibers of the hoop as a whole would show an elastic limit equal to that of the metal as determined by the tests of bars, and incidentally to determine a useful limit for the shrinkage of a similar hoop in gun construction. The object of the second was to determine the behavior of the hoop when subjected to such a shrinkage as would strain its fibers to at least twice the limit of elasticity of the metal as determined by the tests of bars.

The principal observations in each test consisted in measurements of the interior and exterior diameters of the hoop: First, before the shrinkage; second, after the assemblage; and third, after the removal of the cast-iron cylinder, by which was determined the extension of the hoop in place, its restoration on release from the cylinder, and its final set. The compression of the bore of cast-iron cylinder was also measured.*

The cast-iron used for the test-cylinders was cast for the purpose at the foundry; it was of medium quality—one test for tenacity, taken from the sinking head, gave a result of 26,920 pounds per square inch, and another, from a shot cast from the same metal, 28,050 pounds per square inch.

The dimensions of the hoop and cast-iron cylinders are figured in Plate II, also the details of the cuts made at the extremities of the marked diameters in each end of the cylinders before the assemblage of the hoop to enable the extended diameters of the hoop in place to be measured at the ends. The separate measurements made during the progress of the tests are recorded in Appendix I.

THE ELASTIC TEST.

It being the intention in this test to produce a momentary extension of the interior fibers of the hoop under shrinkage equal to the elastic limit determined by the test of bars, the shrinkage was computed as follows:

Assuming the value 8,000 tons for E_0, the modulus of elasticity for the cast iron, we have besides,

$R_0 = 2.25$, $R_1 = 11.75$, and $R_2 = 15.5$ inches:

$\Theta_1 = 45{,}667$ pounds or 20.387. tons, $E_1 = 13.591$ tons, and $\frac{\Delta R_1}{R_1} =$ 0.0015 inch.

* These results were available as a check upon the work, by comparison with the anticipated theoretical results, but were otherwise not considered essential. By means of them it was further found that the assumed modulus of 8,000 tons for the cast iron was approximately correct.

The interior pressure P_1 required to produce the given relative tangential extension, 0.0015 inch, is found by equation (11), page 5, Notes on Construction of Ordnance, No. 35, viz:

$$P_1=\frac{3\,(R_2^2-R_1^2)\,E_1}{4\,R_2^2+2\,R_1^2}\times\frac{\varDelta R_1}{R_1}=5.052 \text{ tons.}$$

This is the value of the pressure which the shrinkage would produce at the contact surface, and for the value of the shrinkage we have, equation (44), page 28, Note 35:

$$\varphi_1=\frac{(4\,R_0^2+2\,R_1^2)\,P_1}{3\,(R_1^2-R_0^2)\,E_0}+\frac{(4\,R_2^2+2\,R_1^2)\,P_1}{3\,(R_2^2-R_1^2)\,E_1}$$

$$=0.00046907+0.0015=0.00196907$$

and the absolute value $=\varphi_1\times 23.5=0.0463$ inch.

Referring to the measurements pertaining to this test recorded in the Appendix, we find the hoop to have been bored to a mean interior diameter equal to 23.5064 and the exterior of cast iron turned to 23.5502 inches, giving a shrinkage of 0.0438 of an inch absolute and 0.001864 relative value, or 0.0025 of an inch less than prescribed. Also the following: Original mean eccentricity of hoop (interior) 0.0003, and of cylinder (exterior) 0.0005; maximum conicalness of hoop (interior) 0.0016, and of cylinder (exterior) 0.0016 of an inch.

The relative areas in a section perpendicular to the axis of the cylinder and hoop, neglecting the trunnions, was nearly as 1.3 to 1.

The hoop was heated in a hot-air furnace out of contact with flame; the time of heating was 2 hours and 39 minutes; and the expanded diameter when removed from the furnace was 23.580 inches, corresponding to a relative expansion of 3.13 thousandths, a temperature of 550° F. nearly, and giving a diametrical clearance of 0.03 over the cylinder for the assemblage. Seven minutes after the assemblage water was applied to the exterior of the hoop and continued for 23 minutes, until the metal was cool; the heat did not extend perceptibly through to the bore of the cast-iron cylinder.

The measurements to obtain the momentary displacements of the metal were made 44 hours after the shrinkage, and gave the following results:

TABLE A.—*Momentary displacements due to shrinkage in elastic test.*

Subject of measurement.	Displacements.	
	Absolute.	Relative.
	Inches.	*Thousandths.*
Mean compression of bore of cylinder	0.0052	1.15
Mean compression of exterior of cylinder	0.0111	0.47
Extension of interior of hoop:		
On diameter No. 1 (90° from center of trunnions)	0.0346	1.47
Mean of diameters Nos. 2 and 4 (45° from center of trunnions)	0.0337	1.43
On diameter No. 3 (under trunnions)	0.0288	1.23
Mean extension of interior of hoop	0.0327	1.39
Extensions of exterior of hoop:		
On diameter No. 1	0.0302	0.97
Mean of diameters Nos. 2 and 4	0.0292	0.94
Across rimbases (corresponding to diameter No. 3)	0.0247	0.77

The separate diametrical measurements are given to show the influence of the trunnions. On diameter No. 1, perpendicular to the axis of the trunnions, the relative extension, 1.47 thousandths, nearly equals the extension (1.5 thousandths) sought. On Nos. 2 and 4 the momentary extension is less, and there is a marked reduction to 1.23 thousandths on No. 3 directly under the trunnions. The exterior extensions present similar phases. The relative value of the mean interior extension is 1.39 thousandths;* its reduction from the value sought is due to the negative variation of 0.0025 of an inch in the prescribed shrinkage.

The next step in the test was the removal of the cast-iron cylinder. This was cut out in three pieces, allowing entire freedom for the hoop to resume its original dimensions. The results of the measurements then taken, which consisted of a repetition of the original ones, show that the restoration of the hoop on interior diameters 1, 2, and 4 was almost perfect, the average permanent set being 0.0005 of an inch and for diameter No. 1 only 0.0001 of an inch, whilst on No. 3, under the trunnions, the set amounted to 0.0013 of an inch. The results of the exterior measurements give almost identical results.

Under this test the mean eccentricty of the interior of the hoop was increased from 0.0003 to 0.0015 of an inch, and the maximum conicalness from 0.0016 to 0.0019 of an inch.

The peculiarity of these results is that the diameter under the trunnions acquired the only permanent set which can be considered appreciable in practice; yet this was inconsiderable, and, taken as a whole, this test shows that the hoop would not be dangerously strained in gun construction if assembled under a shrinkage calculated to develop the elastic limit, an extension of 0.0015 per linear unit, determined by the specimen tests in the state of action. The metal is shown to possess uniform elastic properties within the limit reached, excepting only a slight impairment in the region of the trunnions. The momentary extension on diameter No. 1 was 1.47 thousandths, and the permanent set on this diameter was practically nil.

STRENGTH TEST.

In this test the lower and better portion of the casting for the cylinders was used and the bore of the cylinder was made 3.2 inches. The exterior of the cylinder was turned to a diameter of 23.5977 inches for shrinkage. The hoop was used in the state in which it was left by the elastic test, having an interior diameter of 23.5071 inches, and making the shrinkage 0.0906 of an inch in absolute value, or 3.855 thousandths in relative value—the effect being to subject the hoop to a strain somewhat more than twice as great as in the elastic test.

The hoop was heated, as before, in the air-furnace; the time of heating was 4 hours and 20 minutes, producing a relative expansion of 4.974 thousandths and a temperature of about 840° F. The clearance for assemblage was 0.026 of an inch. The cooling with water was commenced two minutes after the assemblage, and continued for one hour until the whole was cool.

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*This average extension indicates a theoretical pressure $P_1 = 4.68$ tons per square inch at the contact surface; from this the theoretical absolute extension for the *exterior* of the hoop should be 0.0288 inch, which is nearly equal to the mean of diameters Nos. 2 and 4 above. The pressure on the exterior of the cast iron being 4.68 tons, the absolute compression of the bore should be 0.0055 inch, and the actual, as shown, is 0.0052 inch. These results substantiate the accuracy of the tests and the practical correctness of the data assumed, indicating, however, that the value 8,000 tons for modulus of cast iron is a little too great.

The measurements for momentary displacements of the metal were made 20 hours after the shrinkage, following which the cast-iron cylinder was cut out as before, and the final measurements of the hoop were made throughout at the same points as the original.

The following table gives the momentary displacements of the metal due to the shrinkage, the restoration of the hoop on removal of the cylinder, and also its permanent displacement or final set compared with original dimensions:

TABLE B.—*Strength test.*

Subject of measurement.	Momentary displacement.		Restoration of hoop.		Final set of hoop.	
	Absolute.	Relative.	Absolute.	Relative.	Absolute.	Relative.
	Inches.	*Thou'ths.*	*Inches.*	*Thou'ths.*	*Inches.*	*Thou'ths.*
Mean compression of bore of cylinder........	0.0049	1.53	....	....	....	....
Mean compression of exterior of cylinder....	0.0122	0.52	....	....	....	....
Extensions at interior of hoop:						
On diameter No. 1	0.0809	3.44	0.0543	2.31	0.0266	1.13
Mean diameters of Nos. 2 and 4	0.0792	3.37	0.0436	1.86	0.0356	1.51
On diameter No. 3	0.0741	3.15	0.0321	1.36	0.0420	1.79
Mean extension of interior of hoop	0.0784	3.34	0.0434	1.85	0.0350	1.49
Extensions at exterior of hoop:						
On diameter No. 1	0.0703	2.27	0.0487	1.573	0.0216	[illegible]
Mean of diameters Nos. 2 and 4	0.0664	2.14	0.0389	1.253	0.0275	[illegible]
On diameter No. 3	0.0659	2.06	0.0261	0.820	[illegible]	[illegible]

Taking the mean compression of exterior of cylinder—relative value 0.52 thousandth—we may deduce by formula (23), page 6, Note on Construction of Ordnance, No. 35, the value of the normal pressure at the contact surface due to the elastic contractile effort of the hoop in its state of extension under the shrinkage; we find,

$$P_1 = \frac{3(R_1^2 - R_0^2)E_0}{4R_0^2 + 2R_1^2} \times 0.00052 = 5.896 \text{ tons per square inch, and thence}$$

derive the tangential tension in the direction of the circumference by the formula—

$$\Theta_1 = \frac{4(R_2^2 + 2R_1^2)P_1}{3(R_2^2 - R_1^2)} = 23.79 \text{ tons} = 53{,}290 \text{ pounds per square inch.}$$

In the elastic test we have, from the momentary extension (supposed wholly elastic) of the hoop, deduced $P_1 = 4.68$ tons, hence for that test we should have $\Theta_1 = 18.886$ tons, or 42,300 pounds per square inch. The mean momentary extension in the elastic test was 1.39 thousandths, for which the corresponding load in the tests of bars was 42,670 pounds, giving a very close agreement between the free tests and the shrinkage test based on the deductions from the formulas. The mean momentary extension in the strength test given above is 3.34 thousandths, and the deduced value of Θ_1 is 53,290 pounds, whilst the load which produced nearly the same extension in the free tests was 48,000 pounds. These comparisons indicate that for strains within the elastic limit a given load will produce nearly the same extension in the hoop as in the specimen, but that for excessive strains the metal retains its elastic strength better in the hoop than in the specimen.

The weakness of the hoop in the vicinity of the trunnions, observed in the elastic test, is more pronounced in this. On diameter No. 1, perpendicular to the axis of the trunnions, the restoration is seen to be 67 per cent. of the mòmentary extension, on Nos. 2 and 4 it is 55 per cent., and on No. 3, through the trunnions, only 43 per cent.

The mean eccentricity of the hoop was increased by this test from 0.0003 of an inch (original) to 0.0058 of an inch, lodged in the diameter under the trunnions. The conicalness was increased from 0.0016 of an inch (original) to 0.0031 of an inch, but in general the contour of the hoop in this respect was not markedly changed, and we conclude that the shrinkage tests prove the different portions of the length of the hoop to have been nearly uniform in strength.

The shrinkage tests have shown that the hoop as a whole is adapted for use in gun construction, using a proper amount of care in the shrinkage; that is to say, the hoop should be assembled with a relatively low shrinkage, since an excess of shrinkage would probably develop a set in the trunnion masses in the state of action. It can scarcely be considered safe to assume that such hoops will work to the average elastic limit determined by the free tests. It would be better to use an elastic limit not much exceeding the lowest of the specimens.

The tests indicate that the weak places of the hoop are in the trunnion masses, and lead to the obvious conclusion that the greatest care should be exercised in the manufacture to obviate this defect as far as possible.

WEST POINT FOUNDRY,
Cold Spring, N. Y., June 24, 1886.

APPENDIX I.

RECORDS OF MEASUREMENTS PERTAINING TO ELASTIC TEST.

[Midvale forged steel trunnion-hoop, 8 THEX.—1885. Cast-iron test cylinder No. 1.]

I.—*Hoop prepared for shrinkage.*

(*a*) Interior diameters throughout.

Distance from top.	Diameter No. 1.	Diameter No. 2.	Diameter No. 3.	Diameter No. 4.	Mean diameters.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
0.1	23.5065	23.5070	23.5070	23.5067	23.5068
1.7	23.5052	23.5057	23.5055	23.5053	23.5054
3.35	23.5068	23.5072	23.5070	23.5070	23.5070
5.0	23.5055	23.5057	23.5055	23.5055	23.5055
6.60	23.5072	23.5070	23.5070	23.5070	23.5070
Means	23.5062	23.5065	23.5064	23.5063	23.5064

(*b*) Interior diameters at ends.

Top	23.5077	23.5082	23.5085	23.5080	23.5081
Bottom	23.5075	23.5075	23.5070	23.5072	23.5073
Means	23.5076	23.5078	23.5077	23.5076	23.5077

(*c*) Exterior diameters at ends.

Top	31.0015	31.0000	*32.0215	30.9990	....
Bottom	31.0005	31.0000	*32.0207	30.9995	....
Means	31.0010	31.0000	*32.0211	30.9992	....

* Measured across rimbases.

II.—*Hoop assembled.*

(*d*) Interior diameters at ends.

Distance from top.	Diameter No. 1.	Diameter No. 2.	Diameter No. 3.	Diameter No. 4.	Mean Diameters.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Top	23.5420	23.5418	23.5370	23.5415	23.5404
Bottom	23.5425	23.5412	23.5360	23.5415	23.5403
Means	23.5423	23.5412	23.5365	23.5415	23.5403

(*e*) Exterior diameters at ends.

Top	31.0315	31.0290	*32.0462	31.0285	....
Bottom	31.0310	31.0290	*32.0454	31.0290	....
Means	31.0312	31.0290	*32.0458	31.0287	....

* Measured across rimbases.

III.—*Hoop after removal of cylinder.*

(*f*) Interior diameters throughout.

0.1	23.5065	23.5085	23.5092	23.5078	23.5080
1.7	23.5052	23.5060	23.5070	23.5062	23.5061
3.35	23.5068	23.5080	23.5082	23.5075	23.5076
5.0	23.5058	23.5063	23.5068	23.5060	23.5062
6.60	23.5073	23.5078	23.5078	23.5072	23.5075
Means	23.5063	23.5073	23.5078	23.5069	23.5071

(*g*) Interior diameters at ends.

Top	23.5080	23.5090	23.5100	23.5088	23.5089
Bottom	23.5075	23.5080	23.5080	23.5072	23.5077
Means	23.5077	23.5085	23.5090	23.5080	23.5083

(*h*) Exterior diameters at ends.

Top	31.0020	31.0010	*32.0238	31.0000	....
Bottom	31.0005	31.0003	*32.0214	30.9995	....
Means	31.0012	31.0006	*32.0226	30.9997	....

* Measured across rimbases.

IV.—*Cast-iron cylinder No.* 1.

(*i*) Exterior diameters prepared for shrinkage.

0.25	23.5510	23.5510	23.5500	23.5505	23.5506
1.85	23.5510	23.5508	23.5510	23.5505	23.5506
3.50	23.5505	23.5505	23.5510	23.5505	23.5506
5.15	23.5503	23.5500	23.5503	23.5495	23.5500
6.75	23.5495	23.5495	23.5490	23.5490	23.5492
Means	23.5505	23.5504	23.5503	23.5500	23.5502

(*j*) Interior diameters.

Distance from top.	Before the shrinkage.	Hoop assembled.
Inches.	*Inches.*	*Inches.*
0.25	4.4975	4.4920
1.85	4.4972	4.4918
3.50	4.4970	4.4915
5.15	4.4970	4.4920
6.75	4.4970	4.4922
Means	4.4971	4.4919

RECORDS OF MEASUREMENTS PERTAINING TO STRENGTH TEST.

[Midvale forged steel trunnion-hoop, 8 THex—1885. Cast-iron test cylinder No. 2.]

V.—*Hoop assembled.*

(*k*) Interior diameters at ends.

Distance from top.	Diameter No. 1.	Diameter No. 2.	Diameter No. 3.	Diameter No. 4.	Mean diameters.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Top	23.5898	23.5888	23.5843	23.5883	23.5878
Bottom	23.5875	23.5860	23.5820	23.5868	23.5856
Means	23.5886	23.5874	23.5831	23.5875	23.5867

(*l*) Exterior diameters at ends.

Top	31.0740	31.0680	*32.0890	31.0672	....
Bottom	31.0690	31.0650	*32.0880	31.0658	....
Means	31.0715	31.0665	*32.0885	31.0665	....

* Measured across rimbases.

VI.—*Hoop after removal of cylinder.*

(*m*) Interior diameters throughout.

0.1	23.5360	23.5448	23.5468	23.5425	23.5425
1.7	23.5362	23.5465	23.5472	23.5435	23.5433
3.35	23.5378	23.5490	23.5500	23.5455	23.5456
5.0	23.5365	23.5478	23.5510	23.5442	23.5449
6.60	23.5325	23.5450	23.5530	23.5432	23.5434
Means	23.5358	23.5466	23.5496	23.5438	23.5439

(*n*) Interior diameters at ends.

Top	23.5355	23.5440	23.5470	23.5422	23.5422
Bottom	23.5330	23.5450	23.5525	23.5422	23.5432
Means	23.5342	23.5445	23.5497	23.5422	23.5427

(*o*) Exterior diameters at ends.

Top	31.0248	31.0270	*32.0588	31.0262	....
Bottom	31.0205	31.0285	*32.0630	31.0270	....
Means	31.0226	31.0277	*32.0609	31.0266	....

* Measured across rimbases.

VII.—*Cast-iron cylinder No. 2.*

(*p*) Exterior diameters prepared for shrinkage.

0.25	23.5980	23.5975	23.5975	23.5973	23.5976
1.85	23.5980	23.5975	23.5978	23.5973	23.5976
3.50	23.5980	23.5978	23.5978	23.5975	23.5978
5.15	23.5980	23.5978	23.5978	23.5978	23.5978
6.75	23.5980	23.5978	23.5978	23.5978	23.5978
Means	23.5980	23.5977	23.5978	23.5975	23.5977

(*q*) Interior diameters.

Distance from top.	Before the shrinkage.	Hoop assembled.
Inches.	*Inches.*	*Inches.*
0.5	3.2450	3.2408
1.85	3.2452	3.2402
3.50	3.2465	3.2410
5.15	3.2462	3.2412
6.75	3.2462	3.2415
Means	3.2458	3.2409

APPENDIX II.

Experimental trunnion-hoop for 8-inch steel breech-loading rifle.

By LIEUT. F. E. HOBBS, ORDNANCE DEPARTMENT.

The manufacture of a forged 8-inch trunnion-hoop in this country was, at the time the Midvale Steel Company contracted for the manufacture of the tube, jacket, and trunnion-hoop forgings, required for an 8-inch steel breech-loading rifle—more a matter of experiment than the manufacture of the tube and jacket. No forged trunnion-hoops had been made. Tube and jacket forgings of smaller size had been successfully produced. The trunnion-hoops manufactured had been cast-steel castings, the physical qualities of which were not so good as desired by the Department, and the manufacturers would not undertake to furnish a casting of the qualities required. It is true an attempt was made by the Midvale Steel Company some time before to forge trunnion-hoops, but as the requirement that the hoops should be forged was not insisted upon, high physical qualities were not required, and the attempt was a failure; nothing further in this line was done until the Department pushed the matter. Little or no information in regard to the qualities of trunnion-hoops was at hand, so in order to obtain absolutely the qualities of a forged trunnion-hoop throughout the mass, to determine consequently the average qualities and what fall in elastic strength there was, if any, toward the middle of the thickness and at the base of the trunnions, and incidentally to give the Midvale Steel Company some little experience with that forging (the trunnion-hoop), in respect to the manufacture of which they had more fear as to their ability than either the tube or jacket, the Department determined in July last, after very full discussion, and after a proposition to manufacture both a forged and cast experimental trunnion-hoop had been decided in the negative, to direct the manufacture of a forged experimental trunnion-hoop of the size required for an 8-inch breech-loading steel rifle, to be left rough as it came from the hammer, except that it was to be bored to within one-eighth inch on a side of the finished interior diameter, and, when oil-tempered, to have as little surplus metal as possible, especially in the vicinity of the trunnions and rimbases; an extra length of 2 inches at each end was allowed for taking test specimens to determine the acceptance of the hoop.

Very low physical qualities were demanded, viz:

In specimens 6 inches long between shoulders and 0.564 of an inch in diameter—

Elastic limit, 45,000 pounds per square inch.
Tensile strength, 95,000 pounds per square inch.
Elongation after rupture, 15 per cent.

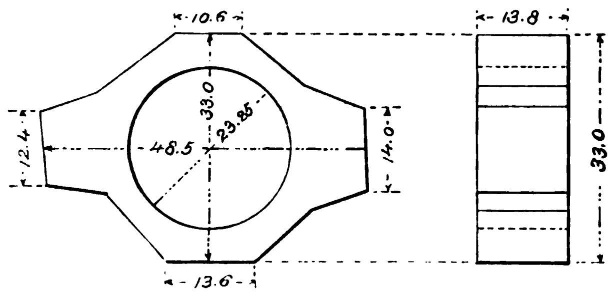
The results of the test of no one specimen to be below—

Elastic limit, 42,000 pounds per square inch.
Tensile strength, 88,000 pounds per square inch.
Elongation after rupture, 12 per cent.

And it was hoped and expected that much higher qualities would be obtained.

Though some difficulty was experienced in forging the hoop, the manufacture throughout was very satisfactory, and much less difficulty was met than had been anticipated. It was made from an ingot weighing about 13,000 pounds, was frequently reheated, and when the operation

of forging was completed varied considerably on the exterior from the required dimensions; so much, in fact, that before treatment metal was cut from it in the vicinity of the rimbases. After this operation and the rough-boring it was of the dimensions shown on the sketch herewith:



The forging was annealed at a high heat before oil-tempering, and after that operation was again annealed at a lower temperature.

* * * * * * *

On acceptance the hoop was shipped to Lieut. R. Birnie, jr., at the works of the West Point Foundry Association, at Cold Spring, N. Y., where it was to be cut up and thoroughly tested, both by further machine tests and by shrinkage tests.

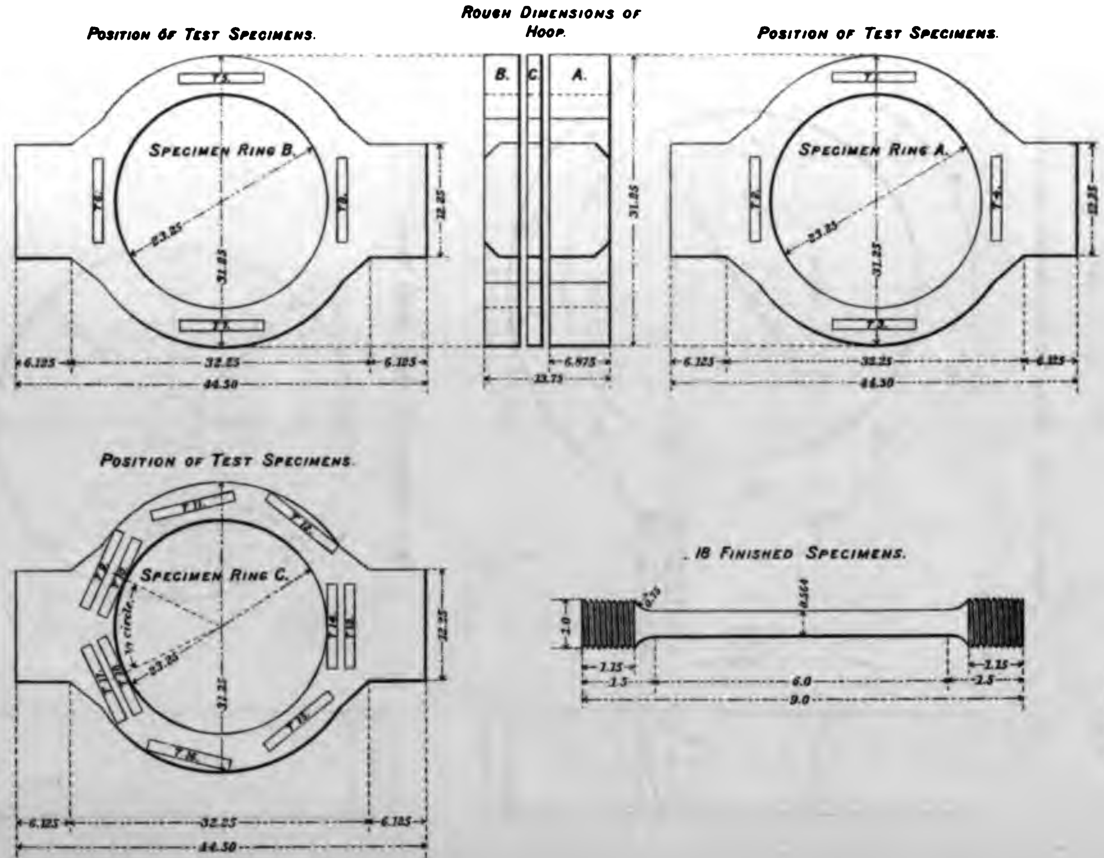
Midvale forged steel.

[Tensile tests: Experimental trunnion-hoop for 8-inch rifle. Specimens 6 inches long between shoulders, and .25 square inch cross-section.]

No.	Marks on specimens.	Specific gravity.	Hardness.	Elastic limit. Pounds per square inch of original section.	Ultimate strength. Pounds per square inch of original section.	Elongation per inch under stress at elastic limit.	Ultimate elongation per inch after rupture.	Reduction in diameter at point of rupture.	Reduction in area after rupture. Per cent. of original section.	Position of rupture.	Character of broken surface, manner of failure, &c.
A..	T_1 M	7.8501	16.56	*50,000	90,440	.001617	19.17	.165	49.7	0".95 from neck	Silky, interspersed with fine granulation.
	T_2 M			55,000	93,600	.001817	17.67	.114	36.4	0".35 from middle of stem	Granular 60 per cent., silky 40 per cent.
	T_3 M			54,000	89,600	.001800	22.17	.181	54.6	1".0 from middle of stem	Fine silky.
	T_4 M			57,000	93,920	.001950	18.00	.161	49.7	At middle of stem	Silky; traces of granulation.
B..	T_5 M			46,000	87,000	.001583	20.33	.175	52.2	.... do	Fine silky.
	T_6 M			47,000	89,000	.001467	17.50	.114	36.4	0".75 from neck	Granular 50 per cent., silky 50 per cent.
	T_7 M			43,000	87,400	.001433	19.83	.155	47.2	1½" from middle of stem	Silky.
	T_8 M			46,000	88,960	.001483	14.50	.154	47.2	¾" from neck	Do.
C..	T_9 O			44,000	81,840	.001483	18.17	.134	41.9	1".25 from neck, oblique	Do.
	T_{10} I			49,000	84,360	.001567	18.83	.204	59.3	2".0 from neck	Fine silky.
	T_{11} M			45,000	86,160	.001433	16.50	.174	52.2	0".85 from neck	Do.
	T_{12} O			48,000	89,280	.001650	16.67	.184	54.6	0".2 from middle of stem	Silky.
	T_{13} O			50,000	91,960	.001717	16.67	.094	30.6	2".7 from neck	Granular. Dull, flaky spot at circumference. Opened cracks in surface of stem.
	T_{14} I			56,000	91,280	.001900	17.83	.184	54.6	2".85 from neck	Silky.
	T_{15} M			47,000	88,960	.001500	19.17	.124	39.2	2".9 from neck	Granular 60 per cent., silky 40 per cent.
	T_{16} O			47,000	87,520	.001617	17.00	.154	47.2	1".85 from neck	Fine silky.
	T_{17} O			45,600	80,760	.001533	18.50	.144	44.6	1".5 from neck	Silky.
	T_{18} I			51,000	84,400	.001733	19.83	.204	59.3	2".5 from neck	Fine silky.

PLATE I.

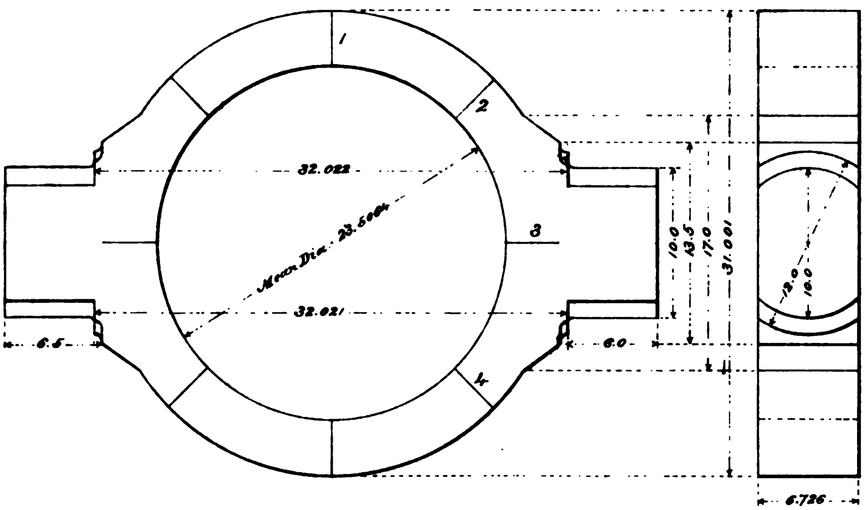
TENSILE TESTS OF ROUND BARS.



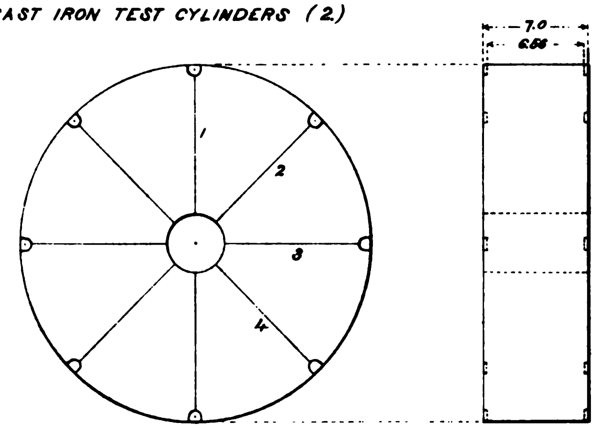
Appendix 26-1886.

SHRINKAGE TESTS.

FINISHED DIMENSIONS OF HOOP: 8TH EX-1885.



CAST IRON TEST CYLINDERS (2.)



No. 1. ELASTIC TEST......{ BORE - Diameter 4.492 inches.
EXTERIOR... „ ...... 23.5502 .. „

No. 2. STRENGTH TEST... { BORE - Diameter 3.246 inches.
EXTERIOR .. „ .. 23.5977.. „

Appendix 26—1886.

H Ex1 pt2 v3 49 2

APPENDIX 27.

LONGITUDINAL STRENGTH OF OIL-TEMPERED AND ANNEALED ROLLED-STEEL GUN-HOOPS.

BY CAPT. ROGERS BIRNIE, JR., ORDNANCE DEPARTMENT.

WEST POINT FOUNDRY,
Cold Spring, N. Y., January 23, 1886.

GENERAL: I have the honor to report herewith the results of tensile tests of specimens taken longitudinally from gun-hoop Bx following its use in shrinkage tests. The experiment was directed by your letter dated September 2, 1885, and the specimens were tested upon the United States testing-machine, Watertown Arsenal, Massachusetts.

Longitudinal strength of oil-tempered and annealed rolled-steel gun-hoops. The test specimens, three in number, were taken near together through the length of the hoop, one outside, one middle, and one inside (see sketch accompanying records of tests herewith). The hoop Bx was one of the original lot made by the Midvale Steel Company for the construction of 8-inch breech-loading steel rifle No. 1 (double-hooped), and before these longitudinal specimens were taken had been used in the construction of an experimental section of that gun. (See Notes on the Construction of Ordnance, No. 32.) The operations of the shrinkage tests are known to have somewhat degraded the tangential strength of the metal, and whilst it is unknown whether or not the longitudinal strength was similarly affected, yet it seems proper in making a comparison of the tangential and longitudinal strength to consider the results of tests made under identical conditions of the metal. Hence we will take the present results to compare with the three given in Table I, Note 32, viz: "B hoop, by tension, after the hooping."

The following table gives a summary of the results derived from the present tests and a comparison of the mean results with those of the three tangential specimens named above:

Subjects of measurements.	Specimens. Load in pounds per square inch.					Percentage of tangential qualities.	
	Longitudinal tests.				Tangential tests. Mean of three specimens.		
	B. L 1 O.	B. L 2 M.	B. L 3 I.	Mean.		Mean loss.	Mean gain.
Length of stem (round) inches..	3.0	3.0	3.0	3.0	6.0	....	....
Sectional area..square inches..	0.25	0.25	0.25	0.25	0.25	....	....
Elongation per inch:							
0.00130	38,000	36,430	37,860	37,430	40,665	7.9	....
0.00135	39,500	37,500	38,830	38,610	42,500	9.1	....
0.00140	41,000	38,750	40,000	39,855	44,110	9.0	....
0.00145	43,250	39,640	40,750	41,215	45,275	9.0	....
0.00150	44,500	40,500	42,000	42,330	46,665	9.3	....
0.00155	45,250	41,500	42,750	43,130	47,665	9.5	....
0.00160	46,000	43,000	43,500	44,165	49,000	9.9	....
0.00165	46,750	43,750	44,250	44,920	50,665	11.3	....
0.00170	....	44,330	45,000	....	51,915	....	....
0.00175	....	44,830	45,750	....	53,275	....	....
Elastic limit	47,000	45,000	49,000	47,000	55,665	15.56	....
Ultimate strength (original section)	99,240	97,600	100,040	98,960	99,653	0.7	....
Elongation per inch at elastic limit..inch..	0.001667	0.001767	0.0020	0.001811	0.001844	1.8	....
Elongation per inch after rupture..inch.	0.2000	0.1733	0.1700	0.1811	0.1456	....	24.3
Reduction in diameter at point of rupture..inch..	0.104	0.094	0.094	0.097	....	....	....
Reduction in area after rupture..per cent..	33.5	30.6	30.6	31.5	....	....	....

We note that the average properties of the metal, as determined by the tensile tests of longitudinal specimens, are: Elastic limit, 47,000, and ultimate resistance, 98,960 pounds per square inch; elongation, per inch at the elastic limit, 1.811 thousandths per linear unit, and ultimate elongation (for a 3-inch specimen), 18.11 per cent. Compared with the tests of specimens taken tangentially, the falling off in the load supported per square inch varies from 8 to 11 per cent. for relative extensions between 1.3 and 1.65 thousandths, and for the load which determines the elastic limit the loss is 15.56 per cent. The elongation at this limit is nearly the same in the two cases, giving at this point a much reduced modulus of elasticity for the longitudinal specimens, but for smaller extensions the difference in the modulii is less marked. The ultimate elongation of the longitudinal specimens shows a higher per cent. than the tangential, but the former specimens were but one-half the length of the latter; yet this ultimate extension of the longitudinal specimens reverts nearly to that given by tangential specimens of the original metal. (See specimens RBx_4 O and RBx_3 I, Table I, Note 32.)

If we compare these results of longitudinal tests with the tangential tests of the original metal (see Table 1, cited above) we find that the falling off of the load at the elastic limit is about 20 per cent., and in the ultimate resistance about 4 per cent. The loss in load for given extensions within the elastic limit varies from 13 to 16 per cent. Since the tendency of the shrinkage is to shorten the length of the hoop, it may be doubted whether there was any loss in the longitudinal strength of this metal attendant upon the shrinkage operations; but, however this may be—and it remains to be proved by comparative tests of metal in its original state—we may conclude from the present experiment that the elastic strength of rolled-steel hoops, oil-tempered and annealed, is not more than 20 per cent. less in the direction of the length than in the direction of the tangent which corresponds to the principal direction of the fiber elongation due to the rolling, and we may anticipate at least equally good results from hammered hoops. The difference in ultimate strength in favor of the tangential tests appears also to be not greater than 5 per cent. The elastic and ultimate elongation in the direction of the length of the hoop compares favorably with similar properties determined for the direction of the tangent.

Constant reference has here been made to the tangential strength of the metal with a view to determining a rule for estimating the longitudinal strength from the results of tangentinal tests, these being the tests usually made; moreover, the taking of longitudinal specimens is not expedient in view of the relatively large portion of the hoop that would thereby be sacrificed.

Very respectfully your obedient servant,

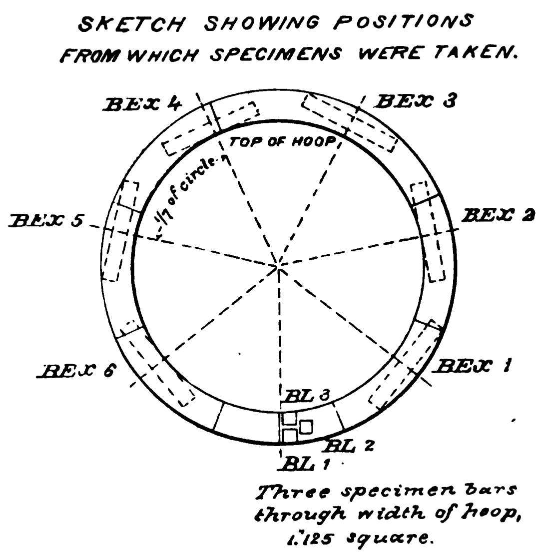
R. BIRNIE, JR.,
Lieutenant of Ordnance.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.

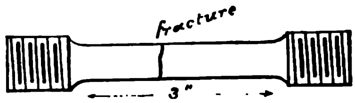
Report of mechanical tests made with the United States testing-machine, capacity 800,000 *pounds, at Watertown Arsenal, Massachusetts, November* 9, 1885, *for the Ordnance Department, U. S. A., Washington, D. C.*

TESTS BY TENSION.

Three specimens taken longitudinally from hoop Bx, 8-inch steel B. L. rifle, subsequent to use in experimental section.



No. 2189.



[Marks: B L 3. Diameter, .564 inch. Sectional area, .25 square inch.]

Total.	Applied loads per square inch.	Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1,000	0	0	0	0	Initial load.
1,250	5,000	.000133	.000133	0	...	
2,500	10,000	.000300	.000167	0	...	
3,750	15,000	.000467	.000167	0	...	
5,000	20,000	.000633	.000166	0	...	
6,250	25,000	.000800	.000167	0	...	
7,500	30,000	.000967	.000167	0	...	
8,750	35,000	.001167	.000200	0	...	
10,000	40,000	.001400	.000233	.000100	.000100	
10,250	41,000	.001467	.000067	...	...	
10,500	42,000	.001500	.000033	...	...	
10,750	43,000	.001567	.000067	...	...	
11,000	44,000	.001633	.000066	...	...	
11,250	45,000	.001700	.000067	.000200	.000100	
11,500	46,000	.001767	.000067	...	...	
11,750	47,000	.000833	.000066	...	...	
12,000	48,000	.001933	.000100	...	...	
12,250	49,000	.002000	.000067	...	...	
12,500	50,000	.002133	.000133	.000433	.000233	Elastic limit. Not well defined.
12,750	51,000	.002233	.000100	...	...	
13,000	52,000	.002367	.000134	...	...	
13,250	53,000	.002533	.000166	...	...	
13,500	54,000	.002767	.000234	...	...	
13,750	55,000	.003167	.000400	...	...	
14,000	56,000	.003533	.000366	...	...	
14,250	57,000	.004067	.000534	...	...	
14,500	58,000	.004700	.000633	...	...	
14,750	59,000	.005267	.000567	...	...	
15,000	60,000	.006000	.000733	...	...	
15,500	62,000	.007667	.001667	...	...	
16,000	64,000	.009200	.001533	...	...	
16,500	66,000	.010833	.001633	...	...	
17,000	68,000	.012400	.001567	...	...	
17,500	70,000	.014333	.001933	...	...	
18,000	72,000	.016200	.001867	...	...	
18,500	74,000	.018000	.001800	...	...	
19,000	76,000	.020000	.002000	...	...	
19,500	78,000	.022167	.002167	...	...	
20,000	80,000	.024533	.002366	...	...	
20,500	82,000	.027433	.002900	...	...	
21,000	84,000	.030000	.002567	...	...	
21,500	86,000	.034667	.004667	...	...	
22,000	88,000	.037667	.003000	...	...	
22,500	90,000	.042333	.004666	...	...	
23,000	92,000	.047333	.005000	...	...	
23,500	94,000	.053333	.006000	...	...	
24,000	96,000	.0667	.013367	...	...	
24,500	98,000	.0767	.0100	...	...	
25,000	100,000	.1067	.0300	...	...	
25,010	100,040	.1333	.0266	...	...	Tensile strength.
23,500	...	...	...	...	...	Load at time of rupture.

GENERAL SUMMARY.

Elongation of inch sections: .14 inch, .25* inch, .12 inch.
Tensile strength per square inch of original section .... pounds.. [illegible]
Elastic limit per inch of original section .... do... [illegible]
Elongation after rupture .... inch.. [illegible]
Elongation under strain at elastic limit .... do... [illegible]
Reduction in diameter at point of rupture .... do... [illegible]
Reduction in area after rupture, per cent. of original section .... [illegible]
Position of rupture, ... .30-inch from middle of [illegible]
Character or broken surface; .... granular; dull, [illegible]

F. H. PARKER,
Major, Ordnance Department, U. S. A., Commanding.

APPENDIX 27*a*.

REPORT ON WINDING AND DISMANTLING AN EXPERIMENTAL WIRE WOUND GUN CYLINDER.

BY LIEUT. WILLIAM CROZIER, ORDNANCE DEPARTMENT.

[1 plate.]

The experiment consisted in winding with steel wire a cylinder cut from the breech end of the casting for the 10-inch cast-iron breech-loading rifle, wire-wound, and afterwards soldering together the wires thus wound, so as to represent a section of the gun through the powder-chamber, with this exception, that, whereas the diameter of the powder-chamber of the gun is 10.85 inches, that of the experimental cylinder was 11 inches, the compound cylinder thus formed being subsequently dismantled by cutting through the wire jacket along a meridian plane.

The wire used was of square cross-section, .15 inch on a side, and was coated with tin after the last drawing. It was drawn at the Trenton Iron Works, of Trenton, N. J., from billets furnished by the Otis Steel Works, of Cleveland, Ohio. The physical qualities were not as uniform as could have been desired, especially the quality of ductility, but in most of the specimens tried the latter was sufficient to permit the wire to be wound around a cylinder of diameter equal to the diagonal of its section. It also contained numerous defects of a more serious nature, which at times caused it to break with a peculiar conical fracture, the fractured surfaces oftentimes showing not more than one-third of the sectional area to be of good metal. None of these breaks, however, occurred during the actual process of winding the cylinder.

The dimensions of the parts are shown in the drawing, Plate I, Fig. 1.

The immediate objects of the experiment were to determine—

(1) Whether reliance could be placed on the formulas giving the normal pressure of a cylinder of wire wound with known tension upon an interior tube.

(2) Whether the means proposed would properly solder together the coils of such a wire cylinder.

(3) The effect of the soldering operation upon the tensions of the coil and the physical qualities of the materials.

(4) The effect upon the physical qualities of the core of the pressure produced by the wire.

From all of which to determine the proper tension for winding the gun.

The physical qualities of the cast iron and of the wire used, adopted from consideration of the free tests of the metals, were as follows:

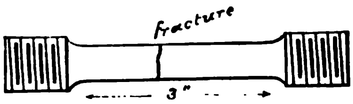
CAST IRON.

		Pounds.
Modulus of elasticity		18,000,000
Elastic limit	under extension	15,000
	under compression	22,400

STEEL WIRE.

Modulus of elasticity	27,000,000
Elastic limit	100,000

No. 2189.



[Marks: B L 3. Diameter, .564 inch. Sectional area, .25 square inch.]

Total.	Applied loads per square inch.	Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1,000	0	0	0	0	Initial load.
1,250	5,000	.000133	.000133	0	....	
2,500	10,000	.000300	.000167	0	....	
3,750	15,000	.000467	.000167	0	....	
5,000	20,000	.000633	.000166	0	....	
6,250	25,000	.000800	.000167	0	....	
7,500	30,000	.000967	.000167	0	....	
8,750	35,000	.001167	.000200	0	....	
10,000	40,000	.001400	.000233	.000100	.000100	
10,250	41,000	.001467	.000067	....	....	
10,500	42,000	.001500	.000033	....	....	
10,750	43,000	.001567	.000067	....	....	
11,000	44,000	.001633	.000066	....	....	
11,250	45,000	.001700	.000067	.000200	.000100	
11,500	46,000	.001767	.000067	....	....	
11,750	47,000	.000833	.000066	....	....	
12,000	18,000	.001933	.000100	....	....	
12,250	49,000	.002000	.000067	....	....	
12,500	50,000	.002133	.000133	.000433	.000233	Elastic limit. Not well defined.
12,750	51,000	.002233	.000100	....	....	
13,000	52,000	.002367	.000134	....	....	
13,250	53,000	.002533	.000166	....	....	
13,500	54,000	.002767	.000234	....	....	
13,750	55,000	.003167	.000400	....	....	
14,000	56,000	.003533	.000366	....	....	
14,250	57,000	.004067	.000534	....	....	
14,500	58,000	.004700	.000633	....	....	
14,750	59,000	.005267	.000567	....	....	
15,000	60,000	.006000	.000733	....	....	
15,500	62,000	.007667	.001667	....	....	
16,000	64,000	.009200	.001533	....	....	
16,500	66,000	.010833	.001633	....	....	
17,000	68,000	.012400	.001567	....	....	
17,500	70,000	.014333	.001933	....	....	
18,000	72,000	.016200	.001867	....	....	
18,500	74,000	.018000	.001800	....	....	
19,000	76,000	.020000	.002000	....	....	
19,500	78,000	.022167	.002167	....	....	
20,000	80,000	.024533	.002366	....	....	
20,500	82,000	.027433	.002900	....	....	
21,000	84,000	.030000	.002567	....	....	
21,500	86,000	.034667	.004667	....	....	
22,000	88,000	.037667	.003000	....	....	
22,500	90,000	.042333	.004666	....	....	
23,000	92,000	.047333	.005000	....	....	
23,500	94,000	.053333	.006000	....	....	
24,000	96,000	.0667	.013367	....	....	
24,500	98,000	.0767	.0100	....	....	
25,000	100,000	.1067	.0300	....	....	
25,010	100,040	.1333	.0266	....	....	Tensile strength.
23,500	....	....	....	....	....	Load at time of rupture.

GENERAL SUMMARY.

Elongation of inch sections: .14 inch, .25* inch, .12 inch.
Tensile strength per square inch of original section .... pounds.. 100,040
Elastic limit per inch of original section .... do... 50,000
Elongation after rupture .... inch.. 0.1700
Elongation under strain at elastic limit .... do... .002133
Reduction in diameter at point of rupture .... do... .094
Reduction in area after rupture, per cent. of original section 38.6
Position of rupture, ... .30-inch from middle of stem.
Character of broken surface: .... granular; dull, eccentric spot.

F. H. PARKER,
Major, Ordnance Department, U. S. A., Commanding.

APPENDIX 27*a*.

REPORT ON WINDING AND DISMANTLING AN EXPERIMENTAL WIRE WOUND GUN CYLINDER.

BY LIEUT. WILLIAM CROZIER, ORDNANCE DEPARTMENT.

[1 plate.]

The experiment consisted in winding with steel wire a cylinder cut from the breech end of the casting for the 10-inch cast-iron breech-loading rifle, wire-wound, and afterwards soldering together the wires thus wound, so as to represent a section of the gun through the powder-chamber, with this exception, that, whereas the diameter of the powder-chamber of the gun is 10.85 inches, that of the experimental cylinder was 11 inches, the compound cylinder thus formed being subsequently dismantled by cutting through the wire jacket along a meridian plane.

The wire used was of square cross-section, .15 inch on a side, and was coated with tin after the last drawing. It was drawn at the Trenton Iron Works, of Trenton, N. J., from billets furnished by the Otis Steel Works, of Cleveland, Ohio. The physical qualities were not as uniform as could have been desired, especially the quality of ductility, but in most of the specimens tried the latter was sufficient to permit the wire to be wound around a cylinder of diameter equal to the diagonal of its section. It also contained numerous defects of a more serious nature, which at times caused it to break with a peculiar conical fracture, the fractured surfaces oftentimes showing not more than one-third of the sectional area to be of good metal. None of these breaks, however, occurred during the actual process of winding the cylinder.

The dimensions of the parts are shown in the drawing, Plate I, Fig. 1.

The immediate objects of the experiment were to determine—

(1) Whether reliance could be placed on the formulas giving the normal pressure of a cylinder of wire wound with known tension upon an interior tube.

(2) Whether the means proposed would properly solder together the coils of such a wire cylinder.

(3) The effect of the soldering operation upon the tensions of the coil and the physical qualities of the materials.

(4) The effect upon the physical qualities of the core of the pressure produced by the wire.

From all of which to determine the proper tension for winding the gun.

The physical qualities of the cast iron and of the wire used, adopted from consideration of the free tests of the metals, were as follows:

CAST IRON.

		Pounds.
Modulus of elasticity		18,000,000
Elastic limit	under extension	15,000
	under compression	22,400

STEEL WIRE.

Modulus of elasticity	27,000,000
Elastic limit	100,000

One of the difficulties attending the application of formulas to the deduction of the changes of dimensions of a body under stress is the selection of the proper modulus of elasticity of the material. In making the preliminary calculations for this experiment the modulus of the cast iron was taken as 15,000,000 pounds, being the value resulting from the changes of length of a specimen under tensile stresses approaching in intensity its assumed elastic limit; this for the reason that it was intended to use this value in computing the strains in the gun both at rest and under fire, and it was considered desirable, in order to insure the safety of the structure, to have the assumed modulus too low rather than too high.

It is apparent, from an inspection of the copy hereto appended of the record of the compression test of the cast iron from this gun, that 15,000,000 pounds is too small a value to be used, and that 18,000,000 pounds, which was obtained by subtracting from each successive compression per inch the corresponding successive permanent set for all loads from 13,000 to 25,000 pounds per square inch inclusive, and dividing 1,000 by the mean of them, is as fair a one as can be taken. (See Appendix A.)

The value (27,000,000 pounds) for the wire was obtained in the same way, the limiting loads being 20,000 pounds and 40,000 pounds per square inch, these being the approximate limits of its strains in the experiment. (See Appendix B.)

Neither metal shows a well-defined limit of elasticity (cast iron rarely does), and the shape of the pieces of wire tested, they having been previously wound around a mandrel, caused them to take a set in straightening under low tension. The special elasticity of this wire would, however, undoubtedly reach 100,000 pounds, and, as will be seen, it is superabundantly strong for the purposes of this experiment.

In the following pages the effects upon the core of the normal pressures produced by the wire are computed by the formulas of Clavarino (Notes on the Construction of Ordnance, No. 6), and also by those of Lieut. Rogers Birnie, jr., Ordnance Department, U. S. A. (Notes on the Construction of Ordnance, No. 35). The latter formulas differ from the former in that they do not consider any pressure as acting upon the ends or faces of the cylinder. The assumption of Clavarino that the normal pressure on the exterior cylindrical surface acts also on the ends is evidently not applicable, and the results obtained from his formulas are given here, because the formulas have been previously used, and an opportunity is thus afforded for comparison.

The formulas giving the tensions in the wire coil and the pressures produced by it are mainly those of Mr. James A. Longridge, as given in his "Treatise on the Application of Wire to the Construction of Ordnance." It is thought, however, that the deductions here given are more easily comprehended than those in Mr. Longridge's valuable though somewhat labyrinthine work.

Application is also made of Clavarino's idea of extensions to the state of the wire coil, and formulas are deduced showing the extension of the wire at all points.

The computations referring to the state of the core and coil with the system in action are reserved for consideration in a future report.

DETERMINATION OF THE PROPER EXTERIOR PRESSURE ON THE CORE.

In determining this point it must first be decided what is to be the amount of strain that the cast iron shall be subjected to at the place where it is greatest, viz, at the bore. This, it is known, should be as great as is consistent with the preservation of the integrity of the

metal—that is, with the preservation, unimpaired, of its qualities—it being assumed that the thickness of the wire cylinder has been made sufficient to produce such a degree of strain. For the present we will assume this maximum strain to be the previously selected limit of elasticity of the metal.

Let us adopt the following nomenclature:

R_0=interior radius of cast-iron cylinder.

R_1=exterior radius of cast-iron cylinder.

R_2=exterior radius of wire cylinder.

P_1'=normal pressure per square inch upon the cast-iron cylinder when the winding is completed.

ψ_1'=the same after the application of 7 layers.

ψ_1''=the same after the application of 18 layers.

ψ_1'''=the same after the application of 29 layers.

Θ_0=limit of elasticity of cast iron under extension=15,000 pounds.

ρ_0=limit of elasticity of cast iron under compression=22,400 pounds.

Θ_1=limit of elasticity of wire under extension=100,000 pounds.

T=the constant tension of winding.

E_0=modulus of elasticity of cast iron=18,000,000 pounds.

E_1=modulus of elasticity of wire=27,000,000 pounds.

We will first determine the exterior normal pressure necessary to produce at the bore the strain above mentioned, and then the tension of winding required to give this pressure.

We have the following equations:

From Clavarino

$$\frac{\Delta R_0}{R_0}=-\frac{1}{E_0}\cdot\frac{5}{3}\cdot\frac{P_1' R_1^2}{R_1^2-R_0^2}=-\frac{\rho_0}{E_0}=-.001244 \quad . \quad . \quad (1)$$

$$\frac{d\,\Delta R_0}{d\,R_0}=\frac{1}{E_0}\cdot\frac{P_1' R_1^2}{R_1^2-R_0^2}=\frac{\theta_0}{E_0} \qquad = \quad .000833 \quad . \quad . \quad (2)$$

From Birnie

$$\frac{\Delta R_0}{R_0}=-\frac{1}{E_0}\cdot\frac{2 P_1' R_1^2}{R_1^2-R_0^2}=-\frac{\rho_0}{E_0} \qquad =-.001244 \quad . \quad . \quad (1')$$

$$\frac{d\,\Delta R_0}{d\,R_0}=\frac{1}{E_0}\cdot\frac{2}{3}\cdot\frac{P_1' R_1^2}{R_1^2-R_0^2}=\frac{\theta_0}{E_0} \qquad = \quad .000833 \quad . \quad . \quad (2')$$

In which the first members of (1) and (1′) represent the relative distortion (that is, distortion per unit of length) of the metal at the surface of the bore in a tangential direction. This being shown by the negative signs affecting the second members to be a contraction, the second members are placed equal to the allowed limit of contraction. The first members of (2) and (2′) represent the rate of distortion, in a radial direction, at the same surface; the signs of the second members showing them to be rates of elongation, they are placed equal to the allowed relative elongation.

* From (1) and (2) values of P_1' can be deduced, the least should be taken. It is evident that it will be obtained from (1), since $\frac{3}{5}\rho_0<\Theta_0$.

Solving (1):

$$P_1'=\frac{3}{5}\cdot\frac{R_1^2-R_0^2}{R_1^2}\rho_0=11{,}590 \text{ pounds.} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

$$P_1'=\frac{1}{2}\cdot\frac{R_1^2-R_0^2}{R_1^2}\rho_0= 9{,}663 \text{ pounds.} \quad . \quad . \quad . \quad . \quad . \quad (3')$$

* In the following, the descriptions of the operations will be given for Clavarino's formulas only, but they will be equally applicable to those of Birnie, which are correspondingly numbered, with distinguishing marks over the numbers.

DETERMINATION OF TENSION OF WINDING.

The above pressure could be produced by winding in any one of several different ways. That which would appear at first sight to be most desirable is the one which would insure that no part of the wire should be overstrained under fire by causing it to be strained uniformly throughout its mass when the gun is subjected to the greatest interior powder-pressure which it is designed to resist. But subsequent examination will show that so much care is not necessary with this gun; the amount of wire is so largely in excess of what would be necessary in order that it should do its share of the work, that although the strains under fire may be by no means uniform, the greatest to which it is subjected will be much within the limit of its elastic strength. And since it is a fact that, as long as the radii of the cylinders remain the same, the strains due to firing will be *transmitted* in the same way, no matter what may be the previously existing strains provided always that the limit of elasticity is nowhere passed), we know that the state of the core will not be affected by the method of winding selected, and we are allowed some liberty in selecting the most convenient. This, of course, is to wind with uniform tension, and anticipating a little, by assuming that it will fulfill the condition of absence of overstrains in the wire under fire, we may proceed to deduce that which will produce upon the core the pressure P_1' already deduced.

Suppose the winding to be finished to a radius r, producing a pressure on the core p_1, and then to be continued to any other radius r_1, the pressure on the core changing to p_1', the additional winding will also produce a pressure at r which denote by p_1; then, since the contact surfaces of the core and coil remain in contact, equating the expressions for the change of radius of these surfaces (Notes on the Construction of Ordnance, No. 35), we have

$$\frac{(4\,R_0^2+2\,R_1^2)\,(p_1'-p_1)}{(R_1^2-R_0^2)\,E_0}=\frac{(4\,r^2+2\,R_1^2)\,(p_1'-p_1)-6\,r^3\,p_r}{(r^2-R_1^2)\,E_1} \quad . \quad . \quad \text{(A)}$$

solving, with respect to $p_1'-p_1$.

$$p_1'-p_1=\frac{6\,E_0\,(R_1^2-R_0^2)\,r^2\,p_r}{E_1\,(r^2-R_1^2)\,(4\,R_0^2+2\,R_1^2)+E_0\,(R_1^2-R_0^3)\,(4\,r^2+2\,R_1^3)} \quad . \quad \text{(B)}$$

Supposing now τ to be the mean tension of the wires between r and r^1,

$$p_r=\frac{\tau\,(r^1-r)}{r} \qquad (b)$$

substituting this value for p_r in (B), dividing by r^1-r, and reducing the denominator

$$\frac{p_1'-p_1}{r_1-r}=\frac{6\,E_0\,(R_1^2-R_0^2)\,\tau\,r}{\left\{\begin{array}{l}[E^1\,(4\,R_0^2+2\,R_1^2)+4\,E_0\,(R_1^2-R_0^2)]\,r^2\\ \qquad -E_1\,R_1^2\,(4\,R_0^2+2\,R_1^2)+E_0\,2\,R_1^2\,(R_1^2-R_0^2)\end{array}\right\}} \quad . \quad \text{(C)}$$

passing to the limit of both members by making $r_1=r$, which amounts to a successive unwinding of the layers exterior to r:

$$L\left(\frac{p_1^1-p_1}{r^1-r}\right)_{r^1=r}=\frac{d\,p_1}{d\,r}$$

limit of second member = the same with T substituted for τ, since by

taking off all the layers exterior to r, τ becomes the tension of winding; therefore

$$\frac{d\,p_1}{d\,r}=\frac{6\,E_0\,(R_1^2-R_0^2)\,T r}{[E_1\,(4\,R_0^2+2\,R_1^2)+4\,E_0\,(R_1^2-R_0^2)]\,r_2-E_1\,R_1^2\,(4\,R_0^2+2\,R_1^2)+E_0\,2\,R_1^2\,(R_1^2-R_0^2)} \qquad \text{(D)}$$

multiplying by $d\,r$, and integrating between the limits r and R_2,

$$p_1=\frac{3E_0\,(R_1^2-R_0^2)\,T}{E_1\,(4\,R_0^2+2\,R_1^2)+4\,E_0\,(R_1^2-R_0^2)}$$

$$l^{*}\frac{R_1^2[E_1(4R^2+2R_1^2)+4E_0(R_1^2-R_0^2)]-R_1^2[E_1(4\,R_0^2+2R_1^2)-E_0^2(R_1^2-R_0^2)]}{r^2[E_1(4\,R^2+2\,R_1^2)+4\,E_0(R_1^2-R_0^2)[-R_1^2]\,E_1(4\,R_0^2+2\,R_1^2)-E_0^2(R_1^2-R_0^2)]}$$

which gives the pressure on the surface of the core produced by winding from r to R_2. By making

$$\beta=\frac{E_1}{E_0}\cdot\frac{R_1^2+R_0^2}{R_1^2-R_0^2}-\frac{E_1-E_0}{3\,E_0}$$

and

$$n=\frac{R^2}{R_1}$$

this can be placed under the form

$$p_1=\frac{T}{\beta+1}\;l\,\frac{(\beta+1)\,n^2-(\beta-1)}{(\beta+1)\,\frac{r^2}{R_1^2}-(\beta-1)} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \qquad \text{(E)}$$

making in this $r=R_1$, we have

$$P_1^1=\frac{T}{\beta+1}\;l\,\frac{(\beta+1)\,n^2-(\beta-1)}{2} \qquad \text{(F)}$$

solving (F) with respect to T,

$$T=\frac{P_1^1}{\frac{1}{\beta+1}\;l\,\frac{(\beta+1)\,n^2-(\beta-1)}{2}} \qquad \text{(4)}$$

which is the formula sought. Substituting the value of

$\beta=1.810284$, $n^2=1.8779$ and P_1^1 from (3)

$$T=40554 \qquad (5)$$

$$T=33795 \qquad (5')$$

We thus see that, if there were no initial strains in the cylinder, the limiting compression of the bore would be obtained by a tension of winding of 40,554 pounds per square inch, according to Clavarino, whilst according to Birnie one of only 33,795 pounds would be required; results which differ sufficiently to emphasize the necessity for selecting the proper method of deduction. And it may here be stated that the error in Clavarino's assumptions will be more prominently shown in the computations incident to the construction of wire guns than in those relating to guns which are built up by shrinkage, because the same error enters, with the latter, in computing both the normal pressures pro-

* l denotes the Naperian logarithm.

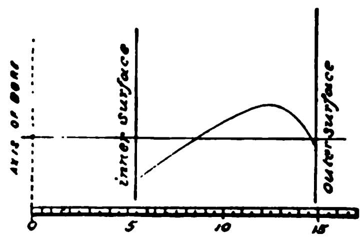
duced by the shrinkages and the distortions produced by these pressures, with counterbalancing effect.

DETERMINING STATE OF INITIAL TENSION OF CYLINDER.

But the condition of absence of initial strains in the cylinder is, presumably, not fulfilled. The gun having been cast breech downward and cooled from the interior, after the Rodman plan, the inner layers should be in a state of compression, gradually decreasing and changing to extension as we proceed outward, this extension increasing until a surface is reached, where, owing to unavoidable cooling from the exterior, it commences to decrease and becomes again compression at the outer surface. So that the initial state may be approximately represented by the curved line in the annexed figure—distances measured above the horizontal line representing extensions, those measured below it contractions.

FIG. 1.

Illustrating initial state of cylinder.



And the final state of the cylinder, after winding, would be represented by a curve whose ordinates should be the algebraic sums of those of the above curve, and of a curve showing, at the different concentric surfaces, the contractions due to the pressure of the wire.

To determine the form of the initial tension curve and the value of its ordinates, a ring was cut from the portion of the sinking head of the gun immediately adjoining that from which the trial cylinder was taken. This ring was scored with concentric circles about 1 inch apart, whose diameters were measured; it was then finished to the radial dimensions of the trial cylinder and the diameters of the circles again measured. In this state it had the initial condition of the trial cylinder. It was then cut into concentric rings a little less than 1 inch in thickness, by cutting midway between the scored circles; after which the diameters of the circles were a third time measured, the changes of dimensions indicating the amount and character of the strains to which the small rings were subjected before being cut apart.

The dimensions were measured with great care on four different diameters making equal angles with each other.

The form of the ring and the positions of the circles and cuts are shown on Plate 1, Fig. 2. The means of the measurements, and the results deduced from them, are given in the following table.

The + sign preceding the value of the force necessary to restore a ring to a former size indicates that the force is one of extension; the − sign that it is of compression.

The force necessary to restore a ring to a former size is, naturally, the force to which it was subjected in the previous state.

TABLE I.—*Initial tension experiment.*

[Ring as cut from sinking head.]

Diameters	1st circle.	2d circle.	3d circle.	4th circle.	5th circle.	6th circle.	7th circle.	8th circle.	9th circle.	10th circle.	11th circle.	12th circle.
Means	10.0247	12.0139	14.0121	16.0128	18.0151	20.0028	22.0059	24.0058	26.0054	28.0047	....	29.9950
[After finishing to radial dimensions of trial cylinder.]												
Means	....	12.0116	14.0104	16.0109	18.0135	20.0020	22.0045	24.0048	26.0039	28.0034	29.4650	....
[After cutting into small rings.]												
Means	10.0283	12.0144	14.0127	16.0117	18.0136	20.0003	22.0029	24.0024	26.0013	28.0017	29.4655	30.0142
Changes from original measurements	+.0036	+.0014	+.0006	—.0011	—.0015	—.0025	—.0030	—.0034	—.0041	—.0030	....	+.0192
The same per linear inch	+.00036	+.000117	+.000043	—.000069	—.000083	—.000125	—.000137	—.000142	—.000158	—.000107	....	+.00064
Force per square inch, applied tangentially, required to restore to original size	—6,480	—2,106	—774	+1,402	+1,494	+2,250	+2,466	+2,556	+2,844	+1,926	....	—1,152
Changes from second measurements	....	+.0028	+.0023	+.0008	+.0001	—.0017	—.0016	—.0024	—.0026	—.0017	+.0005	....
The same per linear inch	....	+.00023	+.00016	+.00005	+.000006	—.000085	—.000073	—.0001	—.0001	—.000061	+.000017	....
Force per square inch, applied tangentially, required to restore to second size	....	—4,140	—2,880	—900	—108	+1,530	+1,314	+1,800	+1,800	+1,098	—306	....

The unit of length is 1 inch; the unit of force, 1 pound.

From the horizontal line in the table, giving the values of the force per square inch, necessary to restore the rings to their original sizes, is constructed the curve in Fig. 2. It represents the state of tension of the ring as cut from the sinking head.

From the last line of the table is constructed the curve in Fig. 3. It is the one of which we are to make use, and which was guessed at in Fig. 1.

FIG. 2.

Initial state of rough casting.

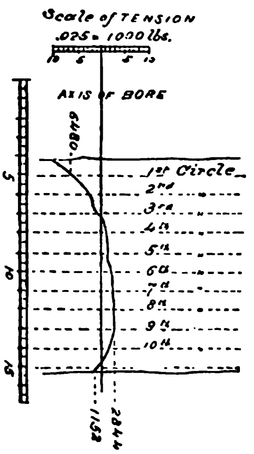
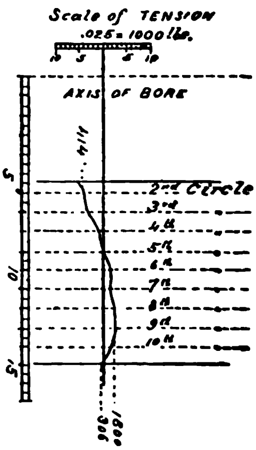


FIG. 3.

Initial state of trial cylinder.



EFFECT OF PRESSURE OF WIRE.

The equation of the curve of relative compressive stresses necessary to produce in free specimens the strains produced at the different radii by the pressure of the wire P_1^1 is:

$$\frac{\Delta r}{r} E_0 = -\frac{P_1^1 R_1^2}{3(R_1^2-R_0^2)}\left(1+\frac{4R_0^2}{r^2}\right) \quad . \quad . \quad . \quad (6)$$

$$\frac{\Delta r}{r} E_0 = -\frac{2 P_1^1 R_1^2}{3(R_1^2-R_0^2)}\left(1+\frac{2R_0^2}{r^2}\right) \quad . \quad . \quad . \quad (6')$$

in which r represents any radius, and the first member represents the relative compressive stress at distance r from the axis of the bore. Assigning values to r, we deduce values as follows for $\frac{\Delta r}{r} E_0$;

$$\left(\frac{\Delta r}{r}\right)_{r=R_0} E_0 = -22{,}400 \text{ pounds } (6)_a = -22{,}400 \text{ pounds } (6')_a$$

$$\left(\frac{\Delta r}{r} E_0\right)_{r=6} = -19{,}537 \text{ pounds } (3)_b = -20{,}015 \text{ pounds } (6')_b$$

$$\left(\frac{J r}{r}\right) E_0 = - \ 15{,}543 \text{ pounds } (6)_c = -16{,}686 \text{ pounds } (6')_c$$
$$r=7$$

$$\left(\frac{J r}{r} E_0\right) = -11{,}172 \text{ pounds } (6)_d = -13{,}044 \text{ pounds } (6')_d$$
$$r=9$$

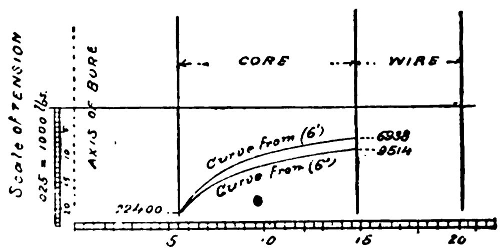
$$\left(\frac{J r}{r} E_0\right) = - \ 8{,}960 \text{ pounds } (6)_e = -11{,}200 \text{ pounds } (6')_e$$
$$r=11$$

$$\left(\frac{J r}{r} E_0\right) = - \ 7{,}688 \text{ pounds } (6)_f = -10{,}139 \text{ pounds } (6')_f$$
$$r=13$$

$$\left(\frac{J r}{r} E_0\right) = - \ 6{,}938 \text{ pounds } (6)_g = - \ 9{,}515 \text{ pounds } (6')_g$$
$$r=14.85$$

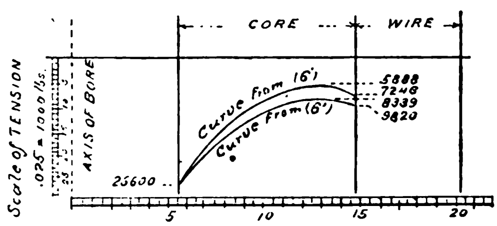
From which we construct the curve below:

FIG. 4.—*State of cylinder due to pressure of wire.*



Combining Fig. 4. and Fig. 3, we obtain—

FIG. 5.—*State of cylinder due to initial tension and pressure of wire.*



From which we see that the total compressive force at the bore would be 26,600 pounds, instead of 22,400 pounds; and if it were intended that this total pressure should not exceed the assumed limit, 22,400 pounds, then, evidently, the initial compression, 4,200 pounds, should first be subtracted from 22,400 pounds, and the remainder substituted for p_0 in (1), from which to deduce $P_1{}^1$.

It being the opinion of some learned in the science of ordnance construction that an initial over compression of the bore improves the qualities of the metal and is advantageous, the selected limit of compression becomes a matter of judgment. Perhaps the only safe rule that can be laid down is that it should never be carried beyond the point at which the free test shows an evident breaking down of the metal.

WINDING OF TRIAL CYLINDER.

In accordance with the desire of the inventor, Dr. W. E. Woodbridge, the wire was applied to the trial cylinder under a tension of 40,000 pounds per square inch, or 900 pounds on the wire.

In order to more thoroughly test the formulas, the faces of the cylinder were scored with concentric circles of the following radii: 7.84 inches, 10.17 inches, 12.5 inches, 14.4 inches, 14.7 inches, at which the decrease of diameters was noted. And in addition to the measurements taken after the winding was completed, the bore was measured after the application, respectively, of 7, 18, and 29 layers of the wire, or after the winding was completed to radii of 15.85, 17.5, and 19.1 inches.

All the measurements were taken by Mr. J. E. Howard, the operator of the testing machine at this arsenal, and his assistant, Mr. Litchfield; and from the excellence of the appliances, the number of measurements taken, and the great care exercised, as well as the skill of the operators, the results can be received with a confidence not always attainable in experiments of this kind.

A record of all the measurements taken is appended. (Appendix C.)

CHANGES OF DIMENSIONS DUE TO WINDING.

We will now proceed to deduce the changes of dimensions due to the application of the wire under a tension of 40,000 pounds per square inch.

After winding 7 layers:

Making, in (F), $T = 40{,}000$, and $n^2 = \frac{15.85^2}{R_1^2} = [.056605^*]$

$$\Psi_1{}^1 = 2{,}542.1 \text{ pounds}$$

then, from (6), $\frac{\Delta R_0}{R_0} = -''.0002727$, and $\Delta R_0 = -''.0015$ . . . . (7)

$$\frac{\Delta R_0}{R_0} = -''.00032724, \text{ and } \Delta R_0 = -''.0018 \quad . \; . \; . \quad (7')$$

After winding 18 layers:

$$n^2 = \frac{17.5^2}{R_1^2} = [.142623]$$

$$\Psi_1'' = 6{,}202.9 \text{ lbs.}$$

$$\frac{\Delta R_0}{R_0} = -''.00066542, \; \Delta R_0 = -''.00365 \quad . \; . \; . \; . \quad (8)$$

$$\frac{\Delta R_0}{R_0} = -''.0007985, \; \Delta R_0 = -''.00439 \quad . \; . \; . \; . \; . \quad (8')$$

---

* The figures inclosed in brackets denote the logarithms of the corresponding numbers.

After winding 29 layers:

$$n^2=\frac{19.1^2}{R_1^2}=[.2186137]$$

$$\Psi_1'''=9{,}280.2 \text{ lbs.}$$

$$\frac{\varDelta R_0}{R_0}=-''.00099553,\ \varDelta R_0=-''.00547 \quad . \quad . \quad . \quad . \quad (9)$$

$$\frac{\varDelta R_0}{R_0}=-''.0011946, \varDelta R_0=-''.000657 \quad . \quad . \quad . \quad . \quad . \quad (9')$$

After the winding is all completed—37 layers:

$$P_1^1=11{,}438 \text{ lbs.}$$

$$\frac{\varDelta R_0}{R_0}=-''.001227,\ \varDelta R_0=-''.00675. \quad . \quad . \quad . \quad . \quad . \quad (10)$$

$$\frac{\varDelta R_0}{R_0}=-''.0014724,\ \varDelta R_0=-''.0081 \quad . \quad . \quad . \quad . \quad . \quad (10')$$

$$\left(\frac{\varDelta r}{r}\right)_{r=7.84}=-''.00072876,\ (\varDelta r)_{r=7.84}=-''.00571 \quad . \quad . \quad . \quad . \quad (11)$$

$$\left(\frac{\varDelta r}{r}\right)_{r=7.84}=-''.00097425,\ (\varDelta r)_{r=7.84}=-''.00763 \quad . \quad . \quad . \quad (11')$$

$$\left(\frac{\varDelta r}{r}\right)_{r=10.17}=-''.00053269,\ (\varDelta r)_{r=10.17}=-''.005417 \quad . \quad . \quad . \quad (12)$$

$$\left(\frac{\varDelta r}{r}\right)_{r=10.17}=-''.0007782,\ (\varDelta r)_{r=10.17}=-''.007914 \quad . \quad . \quad . \quad (12')$$

$$\left(\frac{\varDelta r}{r}\right)_{r=12.5}=-''.0004356,\ (\varDelta r)_{r=12.5}=-''.00544 \quad . \quad . \quad . \quad (13)$$

$$\left(\frac{\varDelta r}{r}\right)_{r=12.5}=-''.00068109,\ (\varDelta r)_{r=12.5}=-''.0085 \quad . \quad . \quad . \quad . \quad (13')$$

$$\left(\frac{\varDelta r}{r}\right)_{r=14.4}=-''.00038873,\ (\varDelta r)_{r=14.4}=-''.0056 \quad . \quad . \quad . \quad . \quad (14)$$

$$\left(\frac{\varDelta r}{r}\right)_{r=14.4}=-''.00063422,\ (\varDelta r)_{r=14.4}=-''.00913 \quad . \quad . \quad . \quad (14')$$

$$\left(\frac{\varDelta r}{r}\right)_{r=14.7}=-''.00038294,\ (\varDelta r)_{r=14.7}=-''.0056 \quad . \quad . \quad . \quad . \quad (15)$$

$$\left(\frac{\varDelta r}{r}\right)_{r=14.7}=-''.00062845,\ (\varDelta r)_{r=14.7}=-''.00924 \quad . \quad . \quad . \quad (15')$$

For the change in length of the cylinder, represented by Δh, we have—

$$\text{(Clavarino)}\quad \frac{\Delta h}{h}=-\frac{1}{E_0}\cdot\frac{1}{3}\cdot\frac{P_1{}^1 R_1{}^2}{R_1{}^2-R_0{}^2}\quad . \quad . \quad . \qquad (16)$$

$$\text{(Birnie)}\quad \frac{\Delta h}{h}=+\frac{1}{E_0}\cdot\frac{2}{3}\cdot\frac{P_1{}^1 R_1{}^2}{R_1{}^2-R_0{}^2}\quad . \quad . \quad . \qquad (16')$$

from which

$$\frac{\Delta h}{h}=-''.000245,\quad \Delta h=-''.00245\quad . \quad . \quad . \qquad (17)$$

$$\frac{\Delta h}{h}=+''.00049,\quad \Delta h=+''.0049\quad . \quad . \quad . \qquad (17')$$

These results are collected in the following table, where also are shown the forces, in pounds per square inch, necessary to produce in free specimens the same changes of dimensions. The + sign preceding the value of a change of dimension indicates that it is an elongation; the — sign, that it is a contraction. The + sign preceding the value of a force indicates that it is a force of extension; the — sign, that it is of compression.

TABLE II.

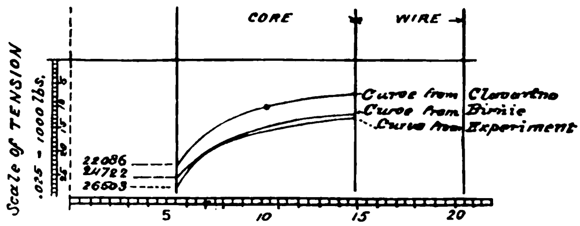
Results of winding.

	Changes of radius of the bore.						Corresponding force.		
	Theoretical.				Actual.		Theoretical.		
	By Clavarino.		By Birnie.						
	Absolute.	Relative.	Absolute.	Relative.	Absolute.	Relative.	Clavarino.	Birnie.	Actual.
After 7 layers	—.0015	—.0002727	—.0018	—.0003272	—.0016	—.0002911	—4,907	—5,890	—5,525
After 18 layers ...	—.0037	—.0006654	—.0044	—.0007915	—.0044	—.0007915	—11,977	—14,373	—14,[illegible]
After 29 layers ...	—.0055	—.0009955	—.0066	—.0011946	—.0068	—.0012454	—17,919	—21,503	—21,[illegible]
After completion of winding, 37 layers	—.0067	—.001227	—.0081	—.0014724	—.0083	—.0015034	—22,086	—26,503	—24,722
CHANGES OF RADII OF FACE-CIRCLES AFTER COMPLETION OF WINDING.									
Radius, 7''.84	—.0057	—.0007288	—.0076	—.0009742	—.0078	—.000996	—13,118	—17,536	—17,7[illegible]
Radius, 10''.17....	—.0054	—.0005327	—.0074	—.0007282	—.0082	—.0008181	—9,589	—14,008	—15,160
Radius, 12''.50....	—.0054	—.0004256	—.0085	—.0006811	—.0087	—.0007000	—7,841	—12,260	—13,166
Radius, 14''.40....	—.0056	—.0003887	—.0091	—.0006312	—.0095	—.0006597	—6,997	—11,416	—12,240
CHANGES OF LENGTH.									
At bore	......	......	......	......	+.00439	+.000439	......	......	+7,[illegible]
At radius, 7''.84 ..	......	......	......	......	+.00422	+.000422	......	......	+7,605
At radius, 10''.17 .	......	......	......	......	+.00322	+.000322	......	......	+5,865
	supposed uniform throughout.								
At radius, 12''.50 .	......	......	......	......	+.00212	+.000212	......	......	+3,525
At radius, 14''.40 .	......	......	......	......	+.00126	+.000126	......	......	+3,272
At radius, 14''.70	......	......	......	......	+.00132	+.000132	......	......	+2,[illegible]
Mean	—.0024	—.00024	+.0049	+.00049	+.00276	+.000276	—4,410	+8,820	+4,965

Although it was desired to do so, it was not found practicable to obtain a reliable measurement of the exterior diameter of the cylinder while the wire was upon it.

From the columns giving the force corresponding to the changes of radial dimensions after the completion of the winding are constructed the following curves:

FIG. 6.



Those figures in the last column of the above table which relate to radial changes were obtained by taking the measured relative changes of dimensions, with them as argument entering the table of test record appended, Appendix A, finding the corresponding load and from it subtracting 500 pounds, the initial load.

From a general survey of the table it may be said that the agreement between the results obtained by using the formulas for wire pressure in connection with those of Lieutenant Birnie, and the actual results of the experiment, the theoretical final contraction of the radius of the bore being over 97½ per cent. of the actual, is rather remarkable. The discrepancies can nearly all be explained by considering the changing modulus and lack of uniformity of behavior of the material under test. Comparing the actual and theoretical relative changes of radius of the bore, it will be observed that the actual is at first smaller than the theoretical, but as the winding progresses it gains upon it, passing it between the eighteenth and twenty-ninth layers. This is what would be expected from the fact that, whereas the theoretical constant modulus supposes the strains to be always proportional to the stresses, in reality they are not so, but increase more rapidly than the latter, and this especially when the stresses approach their final intensity.

The measurements of the face circles were attended with greater difficulties than those of the bore, and are not so satisfactory. One of these measurements, that marked B^6 (Appendix C), was rejected, being so different from the others as to indicate an abnormal error. The figures given in the table are, with this exception, simple arithmetical means of all the measurements taken. If, instead of taking such means, there had been taken the mean of each set on the face where that set showed the smallest discrepancies, the tabular absolute changes would have been:

For radius.	Corresponding force.
	Pounds.
7.84 — .0079	17,800
10.17 — .00785	14,500
12.59 — .00845	12,450
14.40 — .00885	11,670

which correspond more nearly to the theoretical, and observe the two general laws of change following:

1st. The absolute contraction of radius should change from decreasing to increasing at a distance from the axis of the bore equal to $R_0\sqrt{2}=7''.75$. This might be shown by differentiating the expression for the change, Eq. (6), placing the differential coefficient equal to zero and solving with respect to r.

2d. The absolute contractions should be equal, at the bore and at a distance from the axis of the bore, equal to $2R_0=11$ inches.

STRESSES AT THE BORE REQUIRED FOR DIFFERENT CONTRACTIONS.

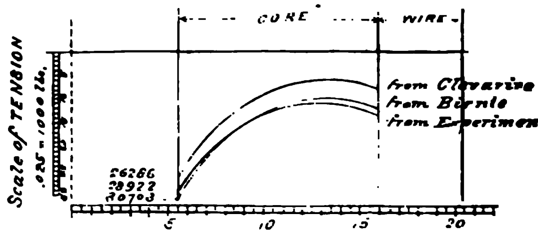
From an examination of the test record we see that to produce the following contractions of the diameter of the bore would require compressive stresses there as stated:

Contractions.	Corresponding force per square inch.
	Pounds.
Absolute: .02, relative: .00182	28,140
Absolute: .04, relative: .00364	37,060
Absolute: .05, relative: .00418	38,580

FINAL STATE OF CORE.

It will be remembered that Table II does not give the exact state of the core, but only the change of state induced by the winding. To obtain the final state, the results in Table I and II should be combined, or the curve of Fig. 3 may be combined, as indicated before, with those of Fig. 6, giving the curves below.

FIG. 7.



Compressive force at bore due to diffent tensions of winding.

From (1) and (F) it is seen that the compressive force at the bore is proportional to the tension of winding, which gives the following theoretical (according to Birnie) total compressive force due to the initial force combined with that due to the different tensions of winding:

Tension of winding.	Corresponding compressive force at bore.	Plus in. comp. 4,200.
Pounds.	*Pounds.*	*Pounds.*
45,000	29,816	34,016
50,000	33,120	37,320
55,000	36,441	40,641

TENSIONS, &c., IN WIRE CYLINDER.

We come now to the consideration of the state of the wire cylinder, and will deduce formulas giving for it the same information that we have previously obtained for the core.

Resuming Equation (B), and supposing the r^1 mentioned above it to be R_2, p_r would then be the pressure at r produced by winding all the wire from r out, or the final pressure at rest at r; and $p_1^1 - p_1$ the pressure on the core produced by the same winding.

Solving (B) with respect to p_r:

$$p_r = \frac{[E_1(4R_0^2+2R_1^2)+4E_0(R_1^2-R_0^2)]r^2 - [E_1(4R_0^2+2R_1^2)-2E_0(R_1^2-R_0^2)]R_1^2}{6E_0(R_1^2-R_0^2)\,r^2}(p_1^1-p_1) \quad \text{(G)}$$

substituting in this for $p_1^1-p_1$ the value of p_1 from (E), and reducing the coefficient by substituting therein the value of β:

$$p_r = \frac{(\beta+1)r^2-(\beta-1)R_1^2}{2r^2}\left\{\frac{T}{\beta+1}\, l\, \frac{(\beta+1)n^2-(\beta-1)}{(\beta+1)\frac{r^2}{R_1^2}-(\beta-1)}\right\} \quad . \quad . \quad \text{(H)}$$

for the pressure at rest at r. Making in this $r=R_1$

$$P_1^1 = \frac{T}{\beta+1}\, l\, \frac{(\beta+1)n^2-(\beta-1)}{2}$$

the same value given in (F), as it should be.

To obtain the tension of the wire at any point: Denote it by t_r. Then τ being the mean tension of the wires in the ring of radii r and r^1, the algebraic difference between the pressures at the surfaces with these radii is in equilibrio with the product of this mean tension into the thickness of the ring, which is expressed by the equation.

$$p_{r'}r^1 - p_r r = -\tau(r^1-r)$$

dividing

$$\frac{p_{r'}r^1-p_r r}{r^1-r} = -\tau$$

passing to the limits of the two members (not by supposing the wires exterior to r to be removed, as with Eq. (b), but by considering successively thinner rings),

$$L\left(\frac{p_{r'}r^1-p_r r}{r^1-r}\right)_{r^1=r} = \frac{d\,(p_r r)}{d\,r}$$

$$L\,(-\tau) = -t_r$$

hence

$$\frac{d\,(p_r r)}{d\,r} = -t_r$$

Substituting the value of p_r from (H) and differentiating:

$$-t_r=\frac{\mathrm{T}}{\beta+1}\,l\,\frac{(\beta+1)\,n^2-(\beta-1)}{(\beta+1)\frac{r_2}{\mathrm{R}_1^2}-(\beta-1)}\left\{\frac{\beta+1}{2}+\frac{\beta-1}{2}\cdot\frac{\mathrm{R}_1^2}{r^2}\right\}$$

$$+\frac{(\beta+1)\,r^2-(\beta-1)\,\mathrm{R}_1^2}{2\,r}\cdot\frac{\mathrm{T}}{\beta+1}\cdot$$

$$\frac{-\left\{(\beta+1)\,n^2-(\beta-1)\right\}\frac{2\,(\beta+1)}{\mathrm{R}_1^2}\,r}{\left\{(\beta+1)\frac{r^2}{\mathrm{R}_1^2}-(\beta-1)\right\}^2}\cdot\frac{(\beta+1)\frac{r^2}{\mathrm{R}_1^2}-(\beta-1)}{(\beta+1)\,n^2-(\beta-1)}$$

$$=\mathrm{T}\left\{\frac{1}{2}+\frac{\beta-1}{\beta+1}\cdot\frac{\mathrm{R}_1^2}{2r^2}\right\}\,l\,\frac{(\beta+1)\,n^2-(\beta-1)}{(\beta+1)\frac{r^2}{\mathrm{R}_1^2}-(\beta-1)}-\mathrm{T}$$

$$t_r=\mathrm{T}\left(1-\frac{(\beta+1)\frac{r^2}{\mathrm{R}_1^2}+(\beta-1)}{2(\mathrm{B}+1)\frac{r^2}{\mathrm{R}_1^2}}\,l\,\frac{(\beta+1)n^2-(\beta-1)}{(\beta+1)\frac{r^2}{\mathrm{R}_1^2}-(\beta-1)}\right)\quad .\ .\ (\mathrm{L})$$

For the tangential *extension* of the wire,

$$\frac{\Delta r}{r}=\frac{1}{\mathrm{E}}\left(t_r+\frac{p_r}{3}\right)=\frac{\mathrm{T}}{\mathrm{E}_1}\left\{1-\frac{(\beta+1)\frac{r^2}{\mathrm{R}_1^2}+\beta-1}{2(\beta+1)\frac{r^2}{\mathrm{R}_1^2}}\,l\,\frac{(\beta+1)n^2-(\beta-1)}{(\beta+1)\frac{r^2}{\mathrm{R}_1^2}-(\beta-1)}+\right.$$

$$\left.\frac{(\beta+1)r^2-(\beta-1)\mathrm{R}_1^2}{6r^2(\beta+1)}\,\frac{(\beta+1)n_2-(\beta-1)}{(\beta+1)\frac{r_2}{\mathrm{R}_1^2}-(\beta-1)}\right\}$$

$$=\frac{\mathrm{T}}{\mathrm{E}_1}\left\{1-\frac{2(\beta-1)+(\beta+1)\frac{r_2}{\mathrm{R}_1^2}}{3(\beta+1)\frac{r_2}{\mathrm{R}_1^2}}\,l\,\frac{(\beta+1)n^2-(\beta-1)}{(\beta+1)\frac{r^2}{\mathrm{R}_1^2}-(\beta-1)}\right\}\quad .\ (\mathrm{M})$$

For the rate of radial extension, multiplying by r, **differentiating and** dividing by $d\,r$:

$$\frac{d\Delta r}{dr}=\frac{\mathrm{T}}{3\mathrm{E}_1}\left\{\frac{5(\beta+1)\frac{r^2}{\mathrm{R}_1^2}+(\beta-1)}{(\beta+1)\frac{r^2}{\mathrm{R}_1^2}-(\beta-1)}+\right.$$

$$\left.\frac{2(\beta-1)-(\beta+1)\frac{r^2}{\mathrm{R}_1^2}}{(\beta+1)\frac{r^2}{\mathrm{R}_1^2}}\,l\,\frac{(\beta+1)n^2-(\beta-1)}{(\beta+1)\frac{r^2}{\mathrm{R}_1^2}-(\beta-1)}\right\}\quad .\ (\mathrm{N})$$

We will construct a curve from Eq. (M), showing for the coil what has been shown by the previous curves for the core, viz. the force necessary to produce in free specimens the tangential strains existing in the coil. It is seen from the form of the equation that

$$\frac{\Delta r}{r}$$

increases with r. Multiplying by E_1,

$$\frac{\Delta r}{r}E_1 = T\left\{1 - \frac{2(\beta-1)+(\beta+1)\frac{r^2}{R_1^2}}{3(\beta+1)\frac{r^2}{R_1^2}} \cdot \frac{(\beta+1)n^2-(\beta-1)}{(\beta+1)\frac{r^2}{R_1^2}-(\beta-1)}\right\}$$

$$=40{,}000\left\{1 - \frac{1.6206+2.8103\frac{r^2}{R_1^2}}{8.4309\frac{r^2}{R_1^2}} \cdot \frac{4.4672}{2.8103\frac{r^2}{R_1^2}-.8103}\right\}$$

$$\left(\frac{\Delta r}{r}E_1\right)=23{,}106 \text{ lbs.}$$

$$r=R_1$$

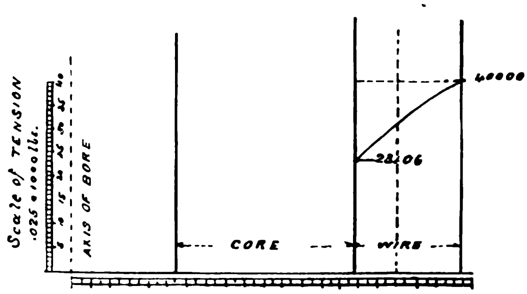
$$\left(\frac{\Delta r}{r}E_1\right)=31{,}523 \text{ lbs.}$$

$$r=17$$

$$\left(\frac{\Delta r}{r}E_1\right)=40{,}000 \text{ lbs.}$$

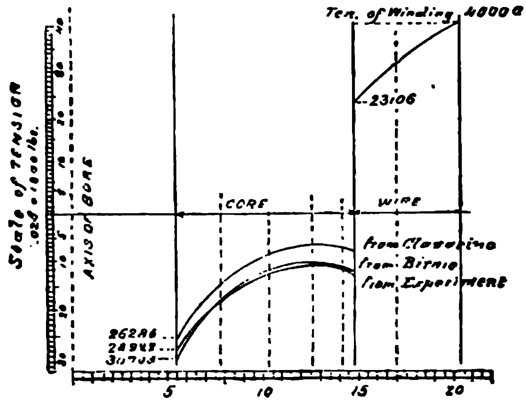
$$r=R_2.$$

FIG. 8.—*State of wire coil.*



Combining Figs. 7 and 8.

FIG. 9.—*State of core and wire due to initial tension of casting and pressure of wire applied under tension of 40,000 pounds per square inch.*



THE PRACTICAL OPERATIONS.

Winding.

A detailed description of the winding-machine used, the invention of Dr. W. E. Woodbridge, will be given in the report on the construction of the gun. It will suffice here to say that the tension was produced by passing the wire between two wooden friction pieces, and afterward three times around a non-revolving disk about 3 feet in diameter, paper of a special description being placed upon the disk for the wire to slide upon, and it was weighed by the amount of compression of two large springs. The lubricant used was a mixture, in definite proportions, of beeswax, paraffine, paraffine oil, and stearic acid.

After a month of trial, incident to the newness of the machine, it was gotten to work so as to apply the wire with quite sufficient accuracy of tension, although, owing principally to the short life of the papers surrounding the disk, the progress was vexatiously slow. Twenty-three working days of eight hours each were required for the completion of the winding, of which, however, four were consumed in taking measurements, and quite a large proportion also required for fitting the tapered filling-in pieces at the ends of each layer. Two wires were wound at a time, the machine being double. The cylinder was supported in a lathe in such a manner as not to interfere with its contraction radially under the increasing pressure of the wire. This was accomplished by means of four studs, distant 90 degrees from each other, left on each face of the cylinder near the bore, the stud sliding in radial grooves cut in arms attached to the arbor.

The spool-rings for confining the wires were upon the arms of the arbor, not attached to the cylinder. Upon removing the arbor and these rings the loose ends of the filling-in pieces projected in every direction, and it was thought that there was danger of the mass of wire falling down and off the core. The pieces, however, were clamped back in their places and firmly secured by solder.

The wires were fastened at the starting ends by bending into a dovetailed notch cut in the core and driving in a wedge from the side; at

the final ends, by soldering and by a thin band of iron passed around and drawn tight by a screw. The winding was continuous.

Soldering.

For the purpose of soldering, the cylinder was inclosed in a case as shown in Plate I, Fig. 3.—a safety-valve being provided to permit the escape of any gas which might be formed within it.

The cylinder, thus incased, was placed in the soldering furnace, mounted upon an arbor the shaft of which projected through a hole in the door of the furnace. The furnace consisted of a large oven, about 33 feet in length, below which, and separated from it, distributed along its length, were six fire-places with brick sides and cast iron tops. Above these and constituting the floor of the oven was a sheet-iron diaphragm, whose object was to disseminate the heat uniformly throughout the oven.

It was at first intended to heat the oven by burning charcoal on the floor of each of the fire-places, but it having been found upon trial, previously made for the purpose, to be impracticable to attain the proper temperature at the ends, the extreme fire-places were provided with grates. Hanging within the oven were eight mercury thermometers which could be viewed from the outside.

The oven was carefully sealed up after the insertion of the cylinder. The fires were started at 5.30 p. m. on January 6, and kept burning until 1 a. m. on January 8.

The oven was very slowly heated up to a temperature of about 500 degrees F.; the cylinder in the mean time being slowly revolved by means of the shaft.

A record of the readings, from the time that the height of the mercury columns permitted them to be taken through the glass-covered apertures provided for the purpose, is appended (Appendix D).

About 4 p. m. on January 7 the furnace was opened at the top and about four and a half gallons of the mixture used for lubricating the wire in winding was poured into the case. The furnace was then closed and the cylinder again revolved. This fluid was intended to completely fill all apertures, to be itself displaced by the solder and form a flux for the soldering.

At 4.45 p. m. the melted solder, composed of two parts by weight of tin to one of lead, was poured in, completely filling the case and rising to the top of the pipe (about 2 feet long) used. The solder was poured from a large ladle with a valve in the bottom. Five hundred and fifty pounds of solder were used.

After pouring the solder the case and furnace were again closed and the cylinder revolved, alternating occasionally in direction, until 1 a. m. on the following morning, when it was stopped and the furnace left to cool off. The rate of revolution was about once per minute.

At 9 a. m. on January 8 small apertures were opened in the end doors of the oven. On January 9 the doors were taken off and the cylinder taken out for removal from the case.

EFFECT OF THE SOLDERING OPERATION UPON THE PRESSURE PRODUCED BY THE WIRE.

The next important step in the progress of the experiment was the remeasuring of the cylinder, for the purpose of ascertaining the effect of soldering operation upon the pressure exerted by the wire cylinder upon the core.

The compound cylinder was taken from its case and the solder carefully removed from the exterior; after which all the radial measurements taken before soldering were repeated. The results are shown in the following table:

TABLE III.—*Effect of soldering operation.*

	Bore.	Radius 7.84.	Radius 10.17.	Radius 12.50.	Radius 14.40.	Radius 14.70.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Radii before soldering	5.49186	7.82920	10.16413	12.50284	14.38814	14.68797
Radii after soldering	5.49341	7.83096	10.16559	12.50521	14.39043	14.68989
Increase	.00155	.00176	.00146	.00237	.00229	.00192
Increase per linear inch	.0002818	.0002245	.0001435	.0001896	.0001590	.0001306
Increase as percentage of original contraction	18.6	22.5	19.7	27.2	24.1	19.5
Indicated relief of pressure on exterior surface, lbs. per square inch	2,127	2,574	2,143	3,111	2,757	2,[illegible]
Corresponding relief of tangential compression at bore	4,928					

It is seen that the recovery is very decided, and sufficiently regular to warrant ascribing it wholly to the relief of pressure on the exterior surface.

The disadvantage of this recovery in a construction where such pressure is a matter of the very first moment needs not to be pressed. Although the percentage of original contraction is in this case known, an extensive series of experiments would be required before sufficient data could be obtained to enable proper allowance for it always to be made.

DISMANTLING THE COMPOUND CYLINDER.

This was accomplished by cutting through the wire cylinder along a meridian plane. The cut was made on the side opposite to that upon which the appearance of the exterior, when the soldering-case was removed, led to the suspicion that the soldering had not been thorough. At the latter place the solder, loosely adhering, showed a change of state, being crystalline, lacking in cohesive strength, and resembling in appearance "dross." This side is supposed to have been uppermost when the revolution of the cylinder in the soldering furnace was stopped, but the evidence upon this point is not conclusive.

Great difficulty was experienced in making the cut, which was done upon a planer, the axis of the cylinder being parallel to the direction of the cut. The loose ends of the wires, as they were successively cut through, would catch upon the tool, impeding its motion and endangering its safety. It was found necessary to clamp them tightly together in order to make the cut at all.

After the first cut was made the cast-iron cylinder was slipped out, and another cut was made dividing the wire cylinder into halves. Nine days were consumed in the operation.

Perhaps no longer description would convey a more accurate idea of the measure of success attending this attempt at soldering than to say that it failed to accomplish the object sought. The wires of a few of the outer layers were soldered (though imperfectly) together laterally;

but even here the successive layers were not united. For a short distance in from the side faces the solder attained its best success; but it altogether failed to penetrate the mass, the wires remaining coated with the lubricant mixture, and tumbling apart upon an attempt being made to handle the cylinder. An occasional wire was stuck to its neighbor through an inch or two of its length, apparently by the melted tin of its coating.

PERMANENT SET OF CORE.

After the wire was removed all the radial measurements of the core, made before winding, were repeated. The results are given in the following table:

TABLE IV.—*Permanent set of core.*

	Bore.	Radius 7.84.	Radius 10.17.	Radius 12.50.	Radius 14.40.	Radius 14.70.	Exterior.
Original radii..........	5.500132	7.83701	10.17241	12.51164	14.39764	14.69842	14.84651
Final radii	5.49876	7.83589	10.17099	12.51030	14.39622	14.69651	14.84528
Set	.00256	.00112	.00142	.00134	.00142	.00191	.00123
Set per linear inch	.000465	.000143	.000139	.000107	.000090	.00013	.000083

The sets accord very closely with those given in the accompanying record of test (Appendix A) as being produced by compressive stresses equivalent to those due to the winding superadded to the initial stresses of casting.

TESTS AFTER DISMANTLING.

After the cylinder was dismantled tests were made of the wire and of the cast iron.

Three pieces of wire were tested, one of which had occupied a position near the inside of the wire cylinder, one near the middle, and one near the outside. The tests showed the qualities to be practically unchanged.

Since in this experiment, and indeed in the gun itself, the wire is not subjected to a strain which can at all be considered a test of its properties, there is no necessity for dwelling longer upon it. It is seen that it is not injuriously affected by annealing during the soldering operation.

It is quite different, however, with the cast iron, which it is proposed to work to the limit of its endurance in resisting both compressive and tensile strains.

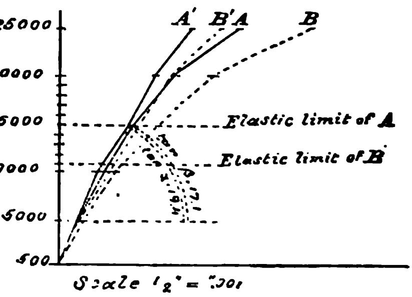
Specimens were taken as represented in Plate I, Fig. 4, and the record of their test is appended (Appendix E). Tangential specimens were taken from the inside only, as that is the only part which endures the greatest strain. From these records and those of the metal made previously to winding are drawn the curves of Figs. 10, 11, and 12.

In these figures the lines A and A′ refer to the metal before winding, B and B′ to it after dismantling. The ordinates represent the stresses per square inch, the abscissas of the lines A and B the corresponding elongations or compressions per inch, those of the lines A′ and B′ the recoveries when the pieces were released; so that the horizontal distances between the lines A and A′ and between B and B′ represent the permanent sets per inch of the specimens to which they refer. The lines A′ and B′ represent the elastic distortions, and may be called the *lines of elasticity*. For the greater part of their length they are practically

straight, and, the ordinates being plotted to a scale of ".1 to 1,000 pounds and the abscissas to one of 1" to ".001, the modulus of elasticity, as the quotient of pounds by inches, is one million times the tangent of the angle which the line of elasticity makes with the axis of abscissas. The curves are so drawn that the effects of the different initial loads (see Appendix) are eliminated.

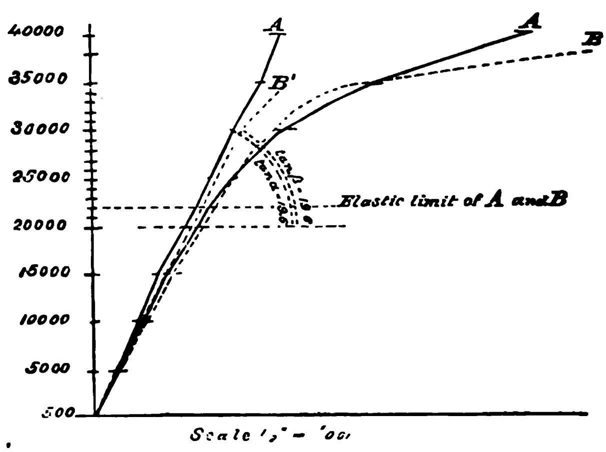
Examining Fig. 10, representing tangential extension, in which points of the curves are constructed for every 5,000 pounds of load, except between the loads 10,000 and 20,000 pounds, where they are constructed for every 1,000 pounds, we see that before winding the modulus, taken between the loads 5,000 and 15,000 pounds, is 19,400,000, and that the line A does not commence to increase with rapidity its distance from A' until it passes the stress of 15,000 pounds, which may therefore be assigned as the elastic limit.

FIG. 10.



Of B the modulus is 17,100,000, and the elastic limit cannot with safety be placed higher than 11,000 pounds. The reduction of the modulus would, if unaccompanied by a decrease of elasticity, be advantageous; but under both considerations this test must be regarded as showing a deterioration in the tensile quality of the metal in this direction.

FIG. 11.



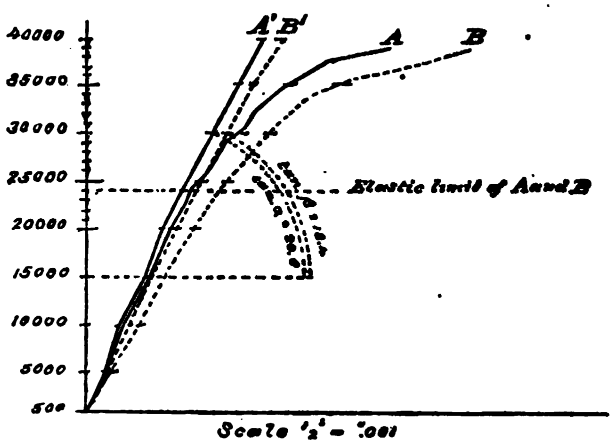
In Fig. 11, tangential compression, points are constructed for every 1,000 pounds between 20,000 and 35,000 pounds. The modulus between

20,000 and 30,000 pounds is 19,600,000 for each specimen. The lines do not show any very marked difference between the pieces. The elastic limit for each may be placed at 22,000 pounds. The specimen before winding is more regular in its action, but after dismantling the compression line departs less from the line of elasticity after passing the assumed elastic limit, and there is not again a decided increase in the sets until 27,000 pounds is reached. The sets above 22,000 pounds are less for the B-line than for the A-line, but the B-line shows its specimen to finally give way suddenly at a lower stress than the other. On the whole the tangential compressive quality of the metal is not much altered; but, as it shows better between the loads 22,000 and 33,000, it may be considered slightly improved.

Fig. 12 relates to radial compression. The modulus before winding is 20,600,000; after dismantling, 18,400,000. Before winding the elastic limit is 24,000, but the departure from the elastic line increases very slightly until after 29,000 is passed. After dismantling the sets commence to increase more rapidly at 24,000 pounds, but from the beginning they are much greater than before winding.

The modulus being reduced and the elasticity being less, the metal is, in respect to resistance to radial compression, undoubtedly deteriorated

Fig. 12.



The total result then is: With respect to tangential extension and radial compression the effect of the exterior pressure is to reduce the modulus and the elasticity, to deteriorate the metal; with respect to tangential compression, to leave the modulus the same and to slightly increase the elasticity, thus improving the metal.

Equations 1 and 2 show that by the exterior pressure on the cylinder the metal is tangentially compressed and radially elongated, which, taken with the above, shows that the resistance to a strain contrary in direction to that to which the metal was subjected in the cylinder is impaired, while that to one in the same direction is improved. This appears quite natural. The elements being crowded together or pulled apart into positions which are not normal, are afterwards pulled or pushed back to place more easily than a similar change of dimensions could have been effected without previous strains, while the new strain

in the same direction indicates the state of special elasticity so often noticed.

The rapid yielding of the metal to compression in both cases after the load 30,000 pounds is passed shows that at no time, either at rest or under fire, should that strain be exceeded.

Fig. 9 shows that the combined strain at the bore, due to the wire and the initial strain of casting, reaches about 30,000 pounds, which is an indication that the tension of winding used, 40,000 pounds per square inch, should not be increased.

Another reason is that under fire the resistance to tangential extension and radial compression are the qualities most needed, and these are the ones which are shown to be impaired by the exterior pressure already attained.

SUMMARY.

The following facts may fairly be considered as having been established by the experiment:

(1) That the machine used can put the wire on with tension at least as high as 900 pounds on the wire, although the progress is slow and the working of the machine is not mechanically satisfactory.

(2) The formulas can be relied upon to give correctly the pressure of the wire cylinder upon the cast-iron one beneath it.

(3) The action of the casting under this pressure shows it to be practically homogeneous throughout.

(4) It is not practicable, by the means proposed, to solder together the coils of the wire cylinder.

(5) The soldering operation diminishes the pressure of the wire upon the core.

(6) This operation does not affect the physical qualities of the wire.

(7) The pressure of the wire decreases the resistance of the cast-iron to strains in a contrary direction to those which it was subjected in the cylinder, and increases its resistance to those in the same direction; consequently,

(8) 40,000 pounds per square inch is as high a tension as should be employed in winding the gun.

This experiment having been carried on concurrently with the construction of the gun and of the plant has been subject to many delays, when it has been necessary that other work should have precedence. But the various stages have been pushed to completion in time to afford information which the progress upon the gun rendered necessary. Of the results obtained bearing upon points to be decided in the construction of the gun the Department has been kept informed.

Of the many difficulties and points of interest in the practical operations but little mention has been made. They will be treated more fully in the report upon the construction of the gun. The following brief abstract from the record gives the dates of the more important operations.

First invoice of wire received June 27, 1885.

Fitting winding machine to lathe, making fixtures, &c.: Commenced July 1, 1885; finished July 20, 1885.

Trying winding machine on old gun, adjusting, altering it, &c.: Commenced July 23, 1885; finished September 5, 1885.

Winding cylinder: Commenced September 19, 1885; finished October 14, 1885.

Casing cylinder for soldering: Commenced November 30, 1885; finished January 5, 1886.

Soldering cylinder: Commenced January 6, 1886; finished January 8, 1886.

Removing cylinder from soldering-case: Commenced January 11, 1886; finished January 23, 1886.

Dismantling the compound cylinder: Commenced February 4, 1886; finished February 12, 1886.

Taking out test specimens from core: Commenced March 9, 1886; finished March 24, 1886.

Measurements were made during winding, in the intervals between winding and casing, removal from case and dismantling, and after dismantling.

The excellent photographs accompanying were made by Capt. John Pitman, Ordnance Department.

For points in regard to the resistance of the materials I am indebted to Mr. J. E. Howard, the engineer operating the testing machine at this Arsenal, whose approval of the discussion and deductions referring to this part of the subject should add to their weight.

APPENDIX A.

Cast iron from breech-disk of 10-inch cast-iron wire-wound rifle.

[No. 308. Mark 4. Diameter, 1.129 inches. Sectional area, 1 square inch. Gauged length, 20 inches.]

Applied Loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	500	0	0	0	0	Initial load.
1,000	1,000	.000015	.000015	0	....	
2,000	2,000	.000060	.000045	0	....	
3,000	3,000	.000110	.000050	0	....	
4,000	4,000	.000160	.000050	0	....	
5,000	5,000	.000220	.000060	.000005	.000005	
6,000	6,000	.000260	.000040	.000010	.000005	
7,000	7,000	.000310	.000050	.000010	0	
8,000	8,000	.000360	.000050	.000010	0	
9,000	9,000	.000425	.000065	.000025	.000015	
10,000	10,000	.000490	.000065	.000040	.000015	
11,000	11,000	.000545	.000055	.000045	.000005	
12,000	12,000	.000610	.000065	.000045	0	
13,000	13,000	.000650	.000040	.000055	.000010	
14,000	14,000	.000720	.000070	.000060	.000005	
15,000	15,000	.000795	.000075	.000065	.000005	Elastic limit.
16,000	16,000	.000870	.000075	.000090	.000025	
17,000	17,000	.000945	.000075	.000100	.000010	
18,000	18,000	.001035	.000090	.000135	.000035	
19,000	19,000	.001125	.000090	.000150	.000015	
20,000	20,000	.001225	.000100	.000190	.000040	
21,000	21,000	.001320	.000095	.000220	.000030	
22,000	22,000	.001445	.000125	.000270	.000050	
23,000	23,000	.001555	.000110	.000320	.000050	
24,000	24,000	.001710	.000155	.000390	.000070	
25,000	25,000	.001880	.000170	.000490	.000100	
26,000	26,000	.002015	.000135	.000550	.000060	
27,000	27,000	.002250	.000235	.000695	.000145	
28,000	28,000	.002540	.000290	.000900	.000205	
29,000	29,000	.002900	.000360	.001185	.000285	
29,120	29,120	....	....	....	....	Tensile strength.

GENERAL SUMMARY.

Tensile strength per square inch of original section ....pounds.. 29,120
Elastic limit per square inch of original section..do ... 15,000
Elongation per inch under strain at elastic limit...inch.. 0.000795

Position of rupture, 2 inches from middle.
Character of broken surface, coarse granular.

No. 362. Mark 7. Length of specimen, 12 inches. Diameter, 1.129 inches. Sectional area, 1 square inch.]

Applied loads, per square inch.	Compression per inch.	Successive compression per inch.	Permanent set.	Successive permanent set.	Remarks.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	0	0	0	0	
1,000	.000020	.000030	0	....	Initial load.
2,000	.000090	.000060	0	....	
3,000	.000130	.000040	0	....	
4,000	.000190	.000060	0	....	
5,000	.000230	.000040	0	....	
6,000	.000290	.000060	0	....	
7,000	.000330	.000040	0	....	
8,000	.000390	.000060	.000030	....	
9,000	.000430	.000040	.000030	....	
10,000	.000500	.000070	.000040	....	
11,000	.000550	.000050	.000050	....	
12,000	.000600	.000050	.000070	....	
13,000	.000680	.000080	.000080	.000010	
14,000	.000710	.000030	.000090	.000010	
15,000	.000770	.000060	.000100	.000010	
16,000	.000840	.000070	.000100	0	
17,000	.000900	.000060	.000100	0	
18,000	.000980	.000080	.000110	.000010	
19,000	.001040	.000060	.000120	.000010	
20,000	.001100	.000060	.000130	.000010	
21,000	.001180	.000080	.000150	.000020	
22,000	.001240	.000060	.000180	.000030	
23,000	.001320	.000080	.000190	.000010	
24,000	.001390	.000070	.000200	.000010	
25,000	.001480	.000090	.000240	.000040	Perceptible deflection.
26,000	.001570	.000090	.000290	.000050	
27,000	.001650	.000080	.000310	.000020	
28,000	.001750	.000100	.000380	.000070	
29,000	.001860	.000110	.000410	.000030	
30,000	.001970	.000110	.000490	.000080	
31,000	.002110	.000140	.000580	.000090	
32,000	.002290	.000180	.000680	.000100	
33,000	.002440	.000150	.000790	.000110	
34,000	.002640	.000200	.000930	.000140	
35,000	.002930	.000290	.001150	.000220	
36,000	.003130	.000200	.001330	.000180	
37,000	.003460	.000330	.001600	.000270	
38,000	.003780	.000320	.001860	.000260	
39,000	.004150	.000370	.002180	.000320	
40,000	.004540	.000390	.002530	.000350	
52,140	....	....	....	....	Ultimate strength.

[No. 365. Mark 10. Length 11.66 inches. Diameter 1.129 inches. Sectional area 1 square inch.]

Applied loads.		Compression per inch.	Successive compression per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	500	0	0	0	0	Initial load.
1,000	1,000	.000018	.000018	0	....	
2,000	2,000	.000036	.000018	0	....	
3,000	3,000	.000072	.000036	0	....	
4,000	4,000	.000109	.000037	0	....	
5,000	5,000	.000164	.000055	0	....	
6,000	6,000	.000217	.000053	0	....	
7,000	7,000	.000273	.000056	0	....	
8,000	8,000	.000309	.000036	0	....	
9,000	9,000	.000345	.000036	0	....	
10,000	10,000	.000381	.000036	.000018	.000018	
11,000	11,000	.000453	.000072	.000018	0	
12,000	12,000	.000489	.000036	.000036	.000018	
13,000	13,000	.000525	.000036	.000036	0	
14,000	14,000	.000561	.000036	.000036	0	
15,000	15,000	.000670	.000109	.000054	.000019	
16,000	16,000	.000688	.000018	.000054	0	
17,000	17,000	.000746	.000058	.000072	.000018	
18,000	18,000	.000800	.000054	.000091	.000019	
19,000	19,000	.000855	.000055	.000109	.000018	
20,000	20,000	.000891	.000036	.000127	.000018	
21,000	21,000	.000963	.000072	.000127	0	
22,000	22,000	.001035	.000072	.000127	0	
23,000	23,000	.001071	.000036	.000127	0	
24,000	24,000	.001143	.000072	.000145	.000018	
25,000	25,000	.001215	.000072	.000145	0	
26,000	26,000	.001287	.000072	.000163	.000018	
27,000	27,000	.001359	.000072	.000181	.000018	
28,000	28,000	.001431	.000072	.000217	.000036	
29,000	29,000	.001467	.000036	.000235	.000018	
30,000	30,000	.001594	.000127	.000253	.000018	Perceptible deflection.
31,000	31,000	.001727	.000133	.000307	.000054	
32,000	32,000	.001799	.000072	.000343	.000036	
33,000	33,000	.001891	.000092	.000415	.000072	
34,000	34,000	.001981	.000090	.000469	.000054	
35,000	35,000	.002127	.000146	.000541	.000072	
36,000	36,000	.002345	.000218	.000670	.000129	
37,000	37,000	.002490	.000145	.000779	.000109	
38,000	38,000	.002672	.000182	.000906	.000127	
39,000	39,000	.003000	.000328	.001143	.000237	
40,000	40,000	.003290	.000290	.001359	.000216	
61,900	61,900	....	....	....	....	Ultimate strength.

GENERAL SUMMARY.

Ultimate strength per square inch of original section, pounds 61,900

Manner of failure, triple flexure. Cracks developed on the tension side when the middle deflection reached .38 of an inch.

APPENDIX B.

Tinned-steeled wire.

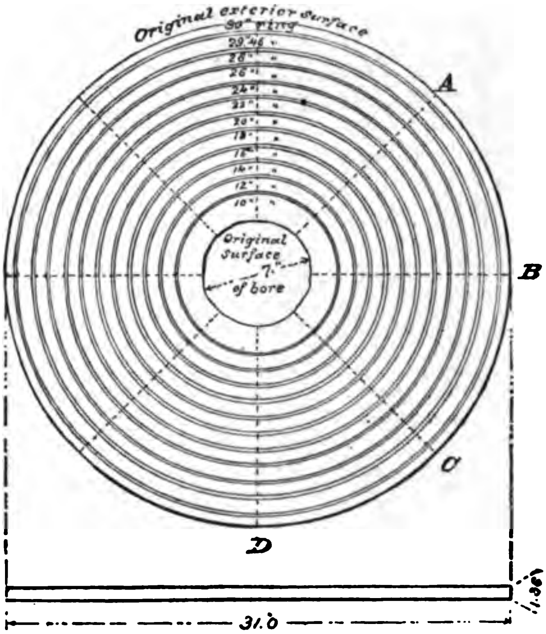
[No. 677. Mark 5. Sectional area .147 by .147 inch. equal .0216 inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
108	5,000	0	0	0	0	Initial load.
216	10,000	.000190	.000190	....	....	
324	15,000	.000380	.000190	....	....	
432	20,000	.000580	.000200	0	....	
540	25,000	.000760	.000180	....	....	
648	30,000	.000930	.000170	....	....	
756	35,000	.001120	.000190	....	....	
864	40,000	.001320	.000200	.000010	.000010	
972	45,000	.001520	.000200	....	....	
1,080	50,000	.001710	.000190	....	....	
1,188	55,000	.001910	.000200	....	....	
1,296	60,000	.002120	.000210	.000080	.000070	
1,404	65,000	.002330	.000210	....	....	
1,512	70,000	.002550	.000220	....	....	
1,620	75,000	.002780	.000230	....	....	
1,728	80,000	.003000	.000220	.000200	.000120	
1,836	85,000	.003220	.000220	....	....	
1,944	90,000	.003470	.000250	....	....	
2,052	95,000	.003700	.000230	....	....	
2,160	100,000	.003970	.000270	.000480	.000280	
2,268	105,000	.004260	.000290	....	....	
2,376	110,000	.004510	.000250	....	....	
2,484	115,000	.004820	.000310	....	....	
2,592	120,000	.005150	.000330	.000810	.000330	
2,700	125,000	.005510	.000360	....	....	
2,808	130,000	.005830	.000320	....	....	
2,916	135,000	.006230	.000400	....	....	
3,024	140,000	.006840	.000610	.001540	.000730	
3,132	145,000	.007300	.000460	....	....	
3,240	150,000	.007970	.000670	....	....	
3,348	155,000	.0085	.000530	....	....	
3,456	160,000	.0095	.0010	....	....	
3,564	165,000	.0110	.0015	....	....	
3,672	170,000	.0130	.0020	....	....	
3,780	175,000	.0160	.0030	....	....	
3,850	178,240	.0290	.0130	....	....	Tensile strength.

APPENDIX C.

Measurements of wire-wound experimental cylinder and initial tension ring.

[Initial tension ring.]



ORIGINAL DIMENSIONS OF RING AS CUT FROM SINKING-HEAD.

[Diameters.]

Ring.	A	B	C	D	Mean.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
30.......	29.9952	29.9901	29.9974	29.9975	29.99505
28.......	28.0090	27.9997	28.0078	28.0022	28.00468
26.......	26.0082	26.0034	26.0040	26.0059	26.00538
24.......	24.0035	24.0075	24.0018	24.0105	24.00583
22.......	22.0045	22.0053	22.0078	22.0061	22.00593
20.......	20.0028	20.0008	20.0064	20.0013	20.00283
18.......	18.0130	18.0155	18.0172	18.0147	18.01510
16.......	16.0112	16.0128	16.0127	16.0144	16.01278
14.......	14.0155	14.0103	14.0133	14.0095	14.01215
12.......	12.0096	12.0156	12.0146	12.0121	12.01298
10.......	10.0266	10.0255	10.0240	10.0229	10.02475

DIMENSIONS AFTER FINISHING TO RADIAL DIMENSIONS OF TRIAL CYLINDER.

30.......	30.0166	30.0496	30.0189	29.9719	30.01425
29.46....	29.4647	29.4635	29.4686	29.4632	29.46500
28......	28.0080	27.9981	28.0065	28.0011	28.00343
26.......	26.0066	26.0014	26.0026	26.0049	26.00388
24.......	24.0020	24.0066	24.0010	24.0095	24.00488
22.......	22.0033	22.0036	22.0066	22.0047	22.00455
20.......	20.0019	19.9997	20.0057	20.0006	20.00198
18.......	18.0118	18.0139	18.0152	18.0130	18.01348
16.......	16.0099	16.0110	16.0102	16.0125	16.01090
14.......	14.0137	14.0088	14.0113	14.0079	14.01042
12.......	12.0084	12.0145	12.0128	12.0109	12.01165
10.......	10.0291	10.0285	10.0294	10.0262	10.02830

Measurements of wire-wound experimental cylinder and initial tension ring—**Continued.**

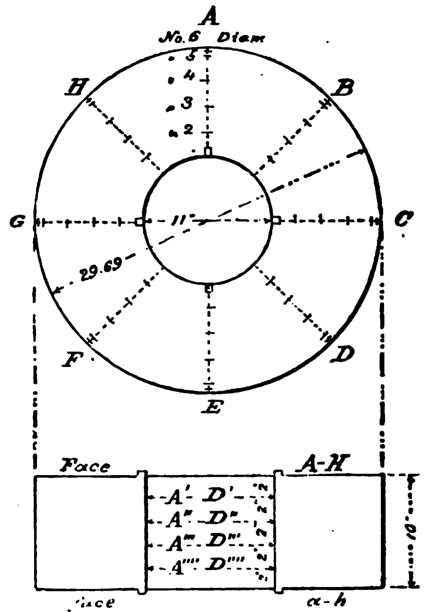
DIMENSIONS OF RINGS AFTER BEING DETACHED.

Ring.	A	B	C	D	Mean.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
30	30. 0168	30. 0496	30. 0189	29. 9719	30. 01425
29. 46....	29. 4630	29. 4665	29. 4709	29. 4618	29. 46555
28	28. 0064	27. 9954	28. 0050	28. 0000	28. 00170
26	26. 0050	25. 9985	25. 9996	26. 0021	26. 00128
24......	24. 0004	24. 0036	23. 9983	24. 0074	24. 00243
22......	22. 0021	22. 0019	22. 0045	22. 0030	22. 00288
20......	20. 0008	19. 9983	20. 0034	19. 9989	20. 00035
18	18. 0122	18. 0142	18. 0152	18. 0130	18. 01365
16.......	16. 0111	16. 0124	16. 0111	16. 0124	16. 01175
14.......	14. 0164	14. 0111	14. 0131	14. 0101	14. 01268
12......	12. 0112	12. 0174	12. 0160	12. 0129	12. 01438
10.......	10. 0291	10. 0285	10. 0294	10. 0262	10. 02830

APPENDIX D.

Experimental cylinder.

[Cast-iron wire-wound.]



EXTERIOR DIAMETER OF CYLINDER BEFORE BEING WIRE-WOUND.

Diameters.	Face A. H.	Distance from face A. H. 2"	4"	6"	8"	Face a. h.	Mean.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
A..........	29. 6926	29. 6931	29. 6925	29. 6926	29. 6914	29. 6921	[illegible]
B..........	29. 6942	29. 6936	29. 6927	29. 6929	29. 6920	29. 6986	29. 69317
C..........	29. 6945	29. 6932	29. 6927	29. 6927	29. 6911	29. 6872	[illegible]
D	29. 6938	29. 6955	29. 6942	29. 6959	29. 6951	29. 6934	[illegible]
Mean..	29. 69377	29. 69385	29. 69302	29. 69353	29. 69240	29. 69157	[illegible]

Experimental cylinder—Continued.

EXTERIOR DIAMETER OF CYLINDER AFTER BEING DISMANTLED.

Diameters.	Face A. H.	Distance from face A. H.				Face a. h.	Mean.
		2″	4″	6″	8″		
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
A..........	29.6908	29.6922	29.6905	29.6857	29.6891	29.6896	29.69032
B..........	29.6922	29.6926	29.6909	29.6899	29.6894	29.6915	29.69108
C..........	29.6922	29.6920	29.6908	29.6897	29.6889	29.6861	29.68995
D..........	29.6915	29.6921	29.6903	29.6902	29.6895	29.6918	29.69090
Mean..	29.69167	29.69223	29.69063	29.68987	29.68922	29.68972	29.69056

ORIGINAL DIMENSIONS OF BORE OF CYLINDER BEFORE BEING WIRE-WOUND.

A..........	11.0016	11.0015	11.0000	11.0001	11.0009	11.0004	11.000750
B..........	11.0006	11.0006	10.9991	10.9905	11.0000	10.9996	10.99990
C..........	11.0006	11.0004	10.9991	10.9994	10.9998	10.9994	10.99978
D..........	11.0014	11.0015	10.9999	11.0000	11.0006	11.0004	11.00063
Mean..	11.00105	11.00100	10.99952	10.99975	11.00032	10.99995	11.000265

DIMENSIONS OF BORE DURING PROGRESS OF WINDING.

Diameters.	Original.	After being wound with—			
		Seven layers of wire.	Eighteen layers of wire.	Twenty-nine layers of wire.	Thirty-seven layers of wire.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
B..............	11.0006	10.9974	10.9920	10.9873	10.9832
D..............	11.0014	10.9981	10.9925	10.9879	10.9846
b..............	10.9996	10.9967	10.9910	10.9860	10.9829
d..............	11.0004	10.9972	10.9917	10.9866	10.9835
Mean....	11.00050	10.99735	10.99180	10.98695	10.98370

DIMENSIONS OF BORE AFTER BEING WOUND WITH THIRTY-SEVEN LAYERS OF WIRE, AND ARBOR REMOVED, BEFORE SOLDERING.

Diameters.	Face A. H.	Distance from face A. H.				Face a. h.	Mean.
		2″	4″	6″	8″		
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
A..............	10.9855	10.9852	10.9836	10.9835	10.9841	10.9840	10.98430
B..............	10.9843	10.9842	10.9827	10.9828	10.9832	10.9827	10.98332
C..............	10.9845	10.9840	10.9828	10.9826	10.9832	10.9830	10.98335
D..............	10.9849	10.9850	10.9832	10.9832	10.9839	10.9833	10.98392
Mean......	10.98480	10.98458	10.98307	10,98303	10.98360	10.98325	10.98372

DIMENSIONS OF BORE AFTER SOLDERING.

A..............	10.9884	10.9881	10.9865	10.9864	10.9872	10.9867	10.98722
B..............	10.9877	10.9877	10.9856	10.9859	10.9865	10.9856	10.98650
C..............	10.9878	10.9873	10.9859	10.9857	10.9863	10.9861	10.98652
D..............	10.9882	10.9882	10.9863	10.9863	10.9871	10.9864	10.98708
Mean......	10.98803	10.98782	10.98608	10.98608	10.98677	10.98620	10.98683

DIMENSIONS OF BORE AFTER CYLINDER WAS DISMANTLED.

A..............	10.9989	10.9988	10.9976	10.9974	10.9981	10.9977	10.99808
B..............	10.9981	10.9980	10.9966	10.9967	10.9972	10.9969	10.99725
C..............	10.9978	10.9975	10.9963	10.9966	10.9971	10.9968	10.99702
D..............	10.9986	10.9987	10.9970	10.9972	10.9979	10.9973	10.99778
Mean......	10.99835	10.99825	10.99687	10.99698	10,99757	10.99718	10.99758

Experimental cylinder—Continued.

MEASUREMENTS OF CYLINDER TAKEN ON SURFACE A. H. BEFORE BEING WIRE-WOUND.

Diameters.	A	B	C	D	Mean.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
2	15.6695	15.6805	15.6745	15.6734	15.67448
3	20.3415	20.3464	20.3486	20.3460	20.34563
4	25.0307	25.0219	25.0302	25.0262	25.02725
5	28.7960	28.7806	28.8032	28.7864	28.79155
6	29.3992	*29.4073	29.3960	29.3976	29.40000

MEASUREMENTS OF CYLINDER TAKEN ON SURFACE A. H. AFTER BEING WOUND WITH THIRTY-SEVEN LAYERS OF WIRE, AND ARBOR REMOVED, BEFORE SOLDERING.

2	15.6539	15.6648	15.6585	15.6575	15.65867
3	20.3256	20.3309	20.3329	20.3304	20.32995
4	25.0139	25.0049	25.0133	25.0091	25.01030
5	28.7775	28.7630	28.7856	28.7693	28.77382
6	29.3741	*29.3672	29.3777	29.3797	29.37468

MEASUREMENTS OF CYLINDER TAKEN ON SURFACE A. H. AFTER SOLDERING.

2	15.6566	15.6685	15.6623	15.6616	15.66225
3	20.3284	20.3338	20.3350	20.3325	20.33242
4	25.0170	25.0085	25.0166	25.0130	25.01378
5	28.7826	28.7667	28.7892	28.7752	28.77842
6	29.3761	29.3707	29.3809	29.3833	29.37825

MEASUREMENTS OF CYLINDER TAKEN ON SURFACE A. H. AFTER BEING DISMANTLED.

2	15.6657	15.6779	15.6717	15.6716	15.67178
3	20.3384	20.3445	20.3456	20.3435	20.34300
4	25.0277	25.0191	25.0274	25.0237	25.02447
5	28.7937	28.7786	28.8012	28.7849	28.78960
6	29.3891	29.3821	29.3925	29.3949	29.38965

MEASUREMENTS OF CYLINDER TAKEN ON SURFACE A. H. BEFORE BEING WIRE-WOUND.

Diameters.	a	b	c	d	Mean.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
2	15.6707	15.6731	15.6739	15.6766	15.67358
3	20.3481	20.3468	20.3371	*20.3334	20.34135
4	25.0257	25.0169	25.0204	25.0142	25.01930
5	28.8006	28.7991	28.7981	28.7983	28.79003
6	29.3978	29.3967	29.3951	29.3948	29.39610

MEASUREMENTS OF CYLINDER TAKEN ON SURFACE A. H. AFTER BEING WOUND WITH THIRTY-SEVEN LAYERS OF WIRE, AND ARBOR REMOVED, BEFORE SOLDERING.

2	15.6555	15.6589	15.6583	15.6599	15.65815
3	20.3304	20.3299	20.3202	*20.3258	20.32658
4	25.0066	24.9985	25.0025	24.9967	25.00108
5	28.7805	28.7805	28.7794	28.7746	28.77875
6	29.3784	29.3776	29.3763	29.3765	29.37720

MEASUREMENTS OF CYLINDER TAKEN ON SURFACE A. H. AFTER SOLDERING.

2	15.6589	15.6614	15.6619	15.6641	15.66158
3	20.3338	20.3333	20.3236	20.3290	20.32993
4	25.0109	25.0020	25.0062	25.0092	25.00708
5	28.7857	28.7850	28.7839	28.7786	28.78330
6	29.3828	29.3821	29.3800	29.3803	29.38130

* Rejected, as the resulting contraction is widely different from that given on the other diameters of the same circle.—W. C.

Experimental cylinder—Continued.

MEASUREMENTS OF CYLINDER TAKEN ON SURFACE A. H. AFTER BEING DISMANTLED.

Diameters.	a	b	c	d	Mean.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
2..........	15. 6690	15. 6718	15. 6723	15. 6740	15. 67178
3..........	20. 3454	20. 3447	20. 3342	20. 3396	20. 34097
4..........	25. 0225	25. 0136	25. 0185	25. 0112	25. 01645
5..........	28. 7977	28. 7970	28. 7957	28. 7908	28. 79530
6..........	29. 3948	29. 3947	29. 3925	29. 3927	29. 39368

LENGTHS OF CYLINDER, MEASURED BEFORE BEING WIRE-WOUND.

Lengths.	A.	B.	C.	D.	E.	F.	G.	H.	Mean.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1........	10. 0018	10. 0008	10. 0023	10. 0008	10. 0018	10. 0000	9. 9998	10. 0003	10. 00095
2........	10. 0020	10. 0024	10. 0003	10. 0020	10. 0020	10. 0000	10. 0006	10. 0018	10. 00139
3........	10. 0008	10. 0009	9. 9995	10. 0001	10. 0001	9. 9980	9. 9983	10. 0001	9. 99972
4........	10. 0006	10. 0008	9. 9995	10. 0002	9. 9997	9. 9975	9. 9975	9. 9997	9. 99944
5........	10. 0005	10. 0007	9. 9987	9. 9997	9. 9994	9. 9965	9. 9968	9. 9989	9. 99890
6........	10. 0004	10. 0007	9. 9985	9. 9995	9. 9992	9. 9960	9. 9970	9. 9989	9. 99878
Mean....	10. 00102	10. 00105	9. 99980	10. 00038	10. 00037	9. 99800	9. 99833	9. 99995	9. 99986

LENGTHS OF CYLINDER, MEASURED AFTER BEING WOUND WITH THIRTY-SEVEN LAYERS OF WIRE.

1........	10. 0069	10. 0049	10. 0072	10. 0051	10. 0059	10. 0040	10. 0039	10. 0038	10. 00521
2........	10. 0062	10. 0068	10. 0054	10. 0063	10. 0064	10. 0039	10. 0045	10. 0054	10. 00561
3........	10. 0038	10. 0046	10. 0030	10. 0034	10. 0033	10. 0011	10. 0012	10. 0032	10. 00295
4........	10. 0029	10. 0027	10. 0017	10. 0020	10. 0016	9. 9987	9. 9997	10. 0032	10. 00156
5........	10. 0021	10. 0019	9. 9995	10. 0007	10. 0005	9. 9972	9. 9980	10. 0014	10. 00016
6........	10. 0021	10. 0019	9. 9995	10. 0007	10. 0005	9. 9967	9. 9980	10. 0014	10. 00010
Mean....	10. 00400	10. 00380	10. 00272	10. 00303	10. 00303	10. 00027	10. 00088	10. 00306	10. 00260

APPENDIX D.

Record of temperatures of soldering furnace.

No. of thermometer.	January 6.					January 7.				
	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 m.	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.
1	....	....	....	....	255	260	278	308	320	332
2	....	....	....	....	268	276	298	316	330	340
3	....	....	....	255	288	300	330	358	370	382
4	....	....	....	256	292	298	330	360	370	380
5	....	....	....	240	270	284	310	334	355	380
6	....	....	....	....	260	270	300	330	342	350
7	197	219	254	280	322	338	390	416	422	422
8	220	228	266	280	308	338	392	420	440	450

No. of thermometer.	January 7.									
	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	12 m.	1 p. m.	2 p. m.	3 p. m.
1	350	358	368	365	374	390	402	390	400	400
2	352	360	374	368	394	414	418	416	416	414
3	405	410	408	400	428	450	446	438	438	440
4	413	408	400	400	434	464	458	454	456	464
5	395	400	388	397	435	445	439	447	447	468
6	370	370	284	397	415	427	429	427	427	437
7	440	445	470	460	484	502	478	480	456	466
8	456	456	446	455	513	524	Too high to be read.			

Record of temperatures of soldering furnaces—Continued.

No. of thermometer.	January 7.									Jan. 8.
	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	9 p. m.	10 p. m.	11 p. m.	12 m.	1 a. m.
1	402	414	426	416	422	424	412	398	404	401
2	418	420	428	428	424	430	424	408	....	422
3	440	448	450	446	444	448	440	428	428	425
4	460	470	460	462	450	458	448	424	424	436
5	468	466	450	439	436	460	460	456	456	445
6	437	438	448	436	430	424	416	422	410	412
7	462	Too high too be read.								
8								512	....	512

No. 7 was directly under No. 2; No. 8 under No. 5.
Fires started at 5.30 p. m., January 6.
Lubricant mixture for flux poured at 4 p. m., January 7.
Solder poured at 4.45 p. m., January 7.
Revolution of cylinder stopped, and furnace left to cool at 1 a. m., January 8.

APPENDIX E.

Cast iron from breech disc of 10-inch cast-iron wire-wound rifle.

[No. 2,601. Mark 3. Diameter, .798 inch. Sectional area .50 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	1,000	0	0	0	0	Initial load.
1,000	2,000	.000050	.000050	....	....	
1,500	3,000	.000100	.000050	....	....	
2,000	4,000	.000167	.000067	....	....	
2,500	5,000	.000233	.000066	0	....	
3,000	6,000	.000300	.000067	....	....	
3,500	7,000	.000350	.000050	....	....	
4,000	8,000	.000417	.000067	....	....	
4,500	9,000	.000483	.000066	....	....	
5,000	10,000	.000567	.000084	.000067	.000067	
5,500	11,000	.000633	.000066	....	....	
6,000	12,000	.000717	.000084	....	....	
6,500	13,000	.000817	.000100	....	....	
7,000	14,000	.000883	.000066	....	....	
7,500	15,000	.001000	.000117	.000183	.000116	
8,000	16,000	.001067	.000067	....	....	
8,500	17,000	.001150	.000083	....	....	
9,000	18,000	.001267	.000117	....	....	
9,500	19,000	.001383	.000116	....	....	
10,000	20,000	.001550	.000167	.000383	.000200	
10,500	21,000	.001650	.000100	....	....	
11,000	22,000	.001800	.000150	....	....	
11,500	23,000	.001983	.000183	....	....	
12,000	24,000	.002183	.000200	....	....	
12,500	25,000	.002500	.000317	.000900	.000517	
14,200	28,400	....	....	....	....	Tensile strength.

Tensile strength (pounds per square inch of original of section), 28,400.

Cast iron from breech disc of 10-inch cast-iron wire-wound rifle—Continued.

[No. 672. Mark 2. Length, 9.05 inches. Diameter, .798 inch. Sectional area, .50 square inch.]

Applied loads.		Compression per inch.	Successive compression per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	1,000	0	0	0	0	Initial load.
1,000	2,000	.000050	.000050	....	....	
1,500	3,000	.000100	.000050	....	....	
2,000	4,000	.000150	.000050	....	....	
2,500	5,000	.000200	.000050	.000017	.000017	
3,000	6,000	.000283	.000083	....	....	
3,500	7,000	.006333	.000050	....	....	
4,000	8,000	.000400	.000067	....	....	
4,500	9,000	.000467	.000067	....	....	
5,000	10,000	.000517	.000050	.000050	.000033	
5,500	11,000	.000567	.000050	....	....	
6,000	12,000	.000633	.000066	....	....	
6,500	13,000	.000683	.000050	....	....	
7,000	14,000	.000750	.000067	....	....	
7,500	15,000	.000817	.000067	.000067	.000017	
8,000	16,000	.000867	.000050	....	....	
8,500	17,000	.000933	.000066	....	....	
9,000	18,000	.001000	.000067	....	....	
9,500	19,000	.001067	.000067	....	....	
10,000	20,000	.001133	.000066	.000100	.000033	
10,500	21,000	.001200	.000067	....	....	
11,000	22,000	.001250	.000050	....	....	
11,500	23,000	.001333	.000083	....	....	
12,000	24,000	.001383	.000050	....	....	
12,500	25,000	.001450	.000067	.000150	.000050	
13,000	26,000	.001517	.000067	....	....	
13,500	27,000	.001583	.000066	....	....	
14,000	28,000	.001683	.000100	....	....	
14,500	29,000	.001750	.000067	....	....	
15,000	30,000	.001867	.000117	.000283	.000133	
15,500	31,000	.002000	.000133	....	....	
16,000	32,000	.002083	.000083	....	....	
16,500	33,000	.002167	.000084	....	....	
17,000	34,000	.002233	.000066	....	....	
17,500	35,000	.002583	.000350	.001033	.000750	
18,000	36,000	.002817	.000234	....	....	
18,500	37,000	.003100	.000283	....	....	
19,000	38,000	.003367	.000267	....	....	
19,500	39,000	.009500	.006133	....	....	
25,490	50,980	....	....	....	....	Ultimate strength.

Ultimate strength (pounds per square inch of original section), 50,980.

Cast iron from breech disc of 10-*inch cast-iron wire-wound rifle*—**Continued.**

[No. 675. Mark 9. Length, 9.01 inches. Diameter, .798 inch. Sectional area, .50 square inch.]

Applied loads. Total.	Applied loads. Per square inch.	Compression per inch.	Successive compression per inch.	Permanent set.	Successive permanent set.	Remarks.
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	1,000	0	0	0	0	Initial load.
1,000	2,000	.000067	.000067	....	....	
1,500	3,000	.000117	.000050	....	....	
2,000	4,000	.000167	.000050	....	....	
2,500	5,000	.000217	.000050	.000033	.000033	
3,000	6,000	.000283	.000066	....	....	
3,500	7,000	.000317	.000034	....	....	
4,000	8,000	.000367	.000050	....	....	
4,500	9,000	.000433	.000066	....	....	
5,000	10,000	.000483	.000050	.000100	.000067	
5,500	11,000	.000550	.000067	....	....	
6,000	12,000	.000600	.000050	....	....	
6,500	13,000	.000650	.000050	....	....	
7,000	14,000	.000717	.000067	....	....	
7,500	15,000	.000767	.000050	.000117	.000017	
8,000	16,000	.000833	.000066	....	....	
8,500	17,000	.000900	.000067	....	....	
9,000	18,000	.000967	.000067	....	....	
9,500	19,000	.001017	.000050	....	....	
10,000	20,000	.001067	.000050	.000167	.000050	
10,500	21,000	.001133	.000066	....	....	
11,000	22,000	.001217	.000084	....	....	
11,500	23,000	.001283	.000066	....	....	
12,000	24,000	.001333	.000050	....	....	
12,500	25,000	.001417	.000084	.000217	.000050	
13,000	26,000	.001500	.000083	....	....	
13,500	27,000	.001583	.000083	....	....	
14,000	28,000	.001667	.000084	....	....	
14,500	29,000	.001750	.000083	....	....	
15,000	30,000	.001900	.000150	.000417	.000200	
15,500	31,000	.002000	.000100	....	....	
16,000	32,000	.002100	.000100	....	....	
16,500	33,000	.002250	.000150	....	....	
17,000	34,000	.002417	.000167	....	....	
17,500	35,000	.002600	.000183	.000833	.000416	
18,000	36,000	.002833	.000233	....	....	
18,500	37,000	.003033	.000200	....	....	
19,000	38,000	.003433	.000400	....	....	
19,500	39,000	.003733	.000300	....	....	
20,000	40,000	.004067	.000334	.002000	.001167	
25,820	51,640	....	....	....	....	Ultimate strength.

Ultimate strength (pounds per square inch of original section), 51,640.

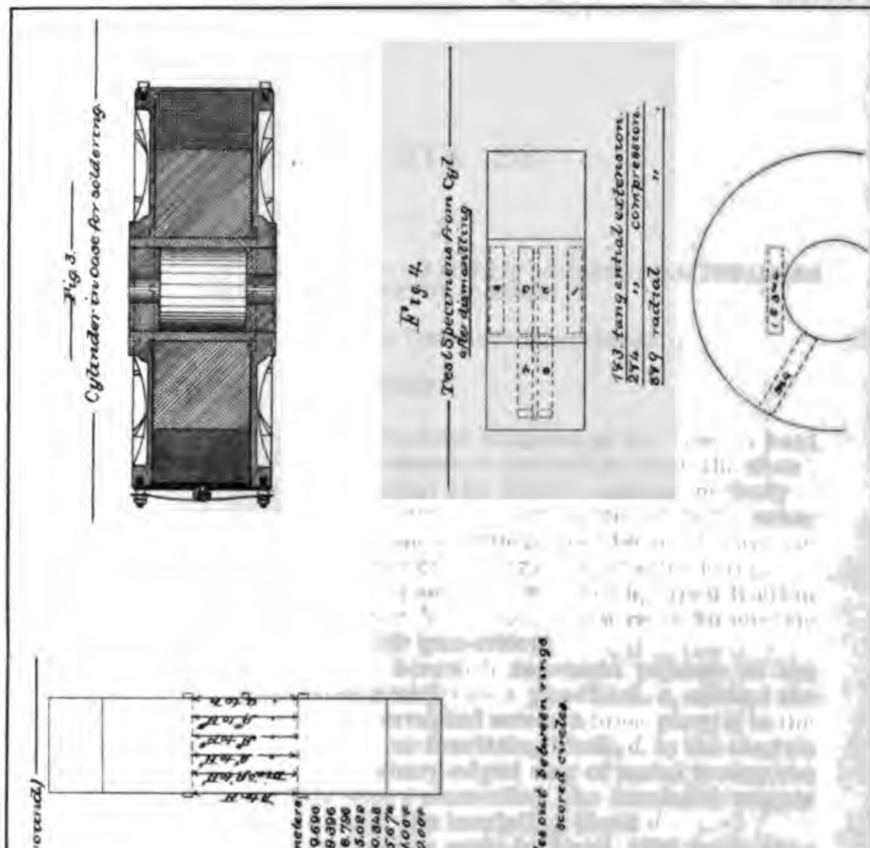


Fig. 1.
Experimental cylinder (wound)
Surface Diameters
External 29.690
6 28.396
5 26.796
4 25.020
3 20.348
2 15.678
Bore 11.004
Length 10.004
Fig. 2.
Initial tension Ring
indicates cut between rings
scored circles
Fig. 3.
Cylinder in case for soldering
Fig. 4.
Test Specimens from Cyl after dismantling
193 tangential extension.
274 " compression.
879 " radial "

Appendix 28.

DESCRIPTION OF FRICTION AND ELECTRIC OBTURATING PRIMERS MADE AT FRANKFORD ARSENAL.

By Capt. J. C. Clifford, Ordnance Department.

(1 plate.)

For the cases of these primers the best material as yet tried is hard rolled brass, a piece of which is reduced at one end to form the shank or part containing the powder charge; the middle portion or body is chased with a screw thread, either entire or interrupted, while the other extremity or head is flattened so that a wrench may be used when required either in inserting the primer or in extracting it after firing.

The friction primer is ignited by a serrated wire acting upon friction composition, and the electric primer by a platinum wire in an electric circuit, the wire being wrapped with gun-cotton.

Figures 1 and 1*a* of the plate herewith represent primers of the model of December, 1885. This model has a gas-check, *a*, around the top of shank, a stop, *b*, for the interrupted screw, a brass plug, *c*, in the friction primer to act as gas-check, an insulating block, *d*, in the electric primer, which is driven against a sharp-edged ring of metal to stop the flow of gas, and the platinum wire *e* connecting the insulated copper wires *f*, which are screwed through the insulating block *d*.

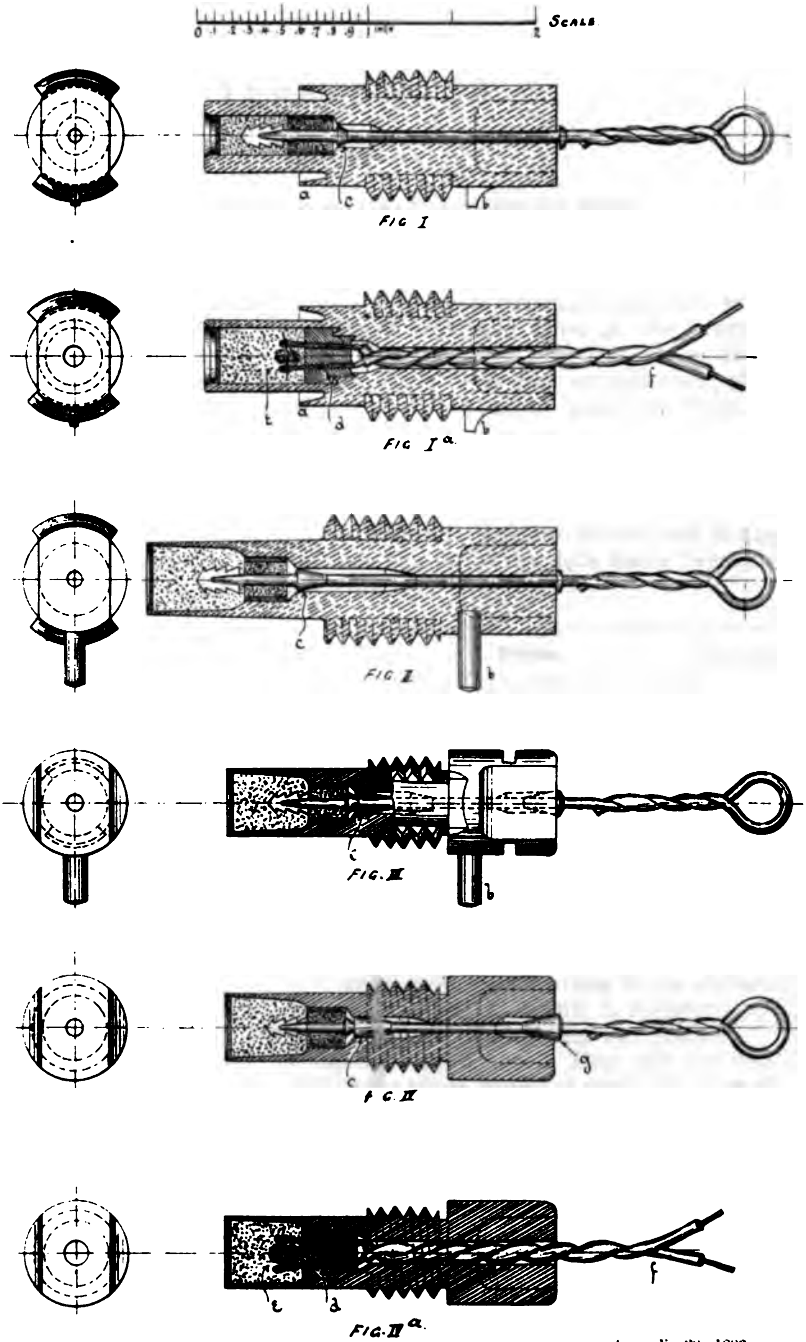
Figure 2 represents a friction primer made in April, 1886, having the metal at mouth of shank thin enough to act as a gas-check.

Figure 3 shows a similar primer, made in the same month with Figure 2, but smaller and notched around the head for extraction by aid of pliers.

Figures 4 and 4*a* represent primers of the model of May, 1886, which were made with a full screw thread, the interior arrangement being essentially the same as in Figures 1 and 1*a* above described.

The enlargement *g* on wire, Figure 4, prevents the serrated part from going too far into the shank of the primer below the friction composition.

OBTURATING FRICTION AND ELECTRIC PRIMERS.



Appendix 28—1886.

APPENDIX 29.

REPORT ON EXPERIMENTAL CANNON POWDER.

BY LIEUT. WILLIAM M. MEDCALF, ORDNANCE DEPARTMENT.

During the year a number of lots of brown prismatic powder have been made at the Du Pont Powder Works, and tried at the proving ground in both the 12-inch B. L. cast-iron rifle and the 8-inch B. L. steel rifle. On the whole the results have been very satisfactory; they equal, and in some cases surpass, those obtained with the German brown powder.

POWDERS FOR 12-INCH B. L. CAST-IRON RIFLES.

The last lot of Du Pont's brown prismatic powder mentioned in the report of 1885 was N M. Since then the following lots have been received and proved in the 12-inch rifle:

Powder.	Density.	Powder.	Density.
N R	1.814	N V, lot 3	1.826
N V, lot 1	1.830	N V, lot 4	1.822
N V, lot 2	1.818	N V, lot 5	1.825

The N V samples tested represent lots of 15,000 pounds, the sample of N R, 2,600 pounds. All the lots except N V, lot 5, were accepted. The sample of this lot gave pressures exceeding the limit of 32,500 pounds fixed by the contract with the makers, and was rejected.

Table 1 gives in condensed form the results obtained in the 12-inch rifle with the different powders, using the maximum charge and heaviest projectile.

Lots 1, 2, and 3 of N V powder were each divided into three sublots of 5,000 pounds each, which were numbered 1, 2, and 3, respectively, and represented as many different methods of blending the grains.

Table 2 gives the results obtained in each case. They are not conclusive as to the comparative advantage of the different methods, though No. 3 appears to favor high velocities and pressures.

The third lot of N V powder shows an improvement over the two preceding lots in uniformity of velocities and pressures.

TABLE 1.—*Table showing the velocities and pressures obtained with different varieties of brown prismatic powder in the 12-inch B. L. cast-iron rifle, with charges of 265 pounds, and an 800-pound projectile, and density of loading of* 0.827.

Kind of powder.	Specific gravity of powder.	Number of rounds considered.	Initial velocity. Greatest.	Initial velocity. Least.	Initial velocity. Mean.	Greatest variation in velocity.	Mean variation in velocity.	Indicated pressure. Greatest pounds per square inch.	Indicated pressure. Least pounds per square inch.	Indicated pressure. Mean pounds per square inch.	Greatest variation in indicated pressure; pounds per square inch.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*				
Du Pont's N. R	1.814	5	1,8[illegible]9	1,766	1,797	73	23.4	33,975	29,900	32,100	4,[illegible]
Du Pont's N. V., lot 1	1.830	7	1,782	1,728	1,757	54	14.4	31,450	24,200	27,370	7,250
Du Pont's N. V., lot 2	1.818	8	1,768	1,683	1,725	85	29.9	30,500	24,825	27,350	5,650
Du Pont's N. V., lot 3	1.826	9	1,727	1,690	1,712	37	10.4	28,000	24,400	26,460	3,600
Du Pont's N. V., lot 4	1.822	3	1,795	1,792	1,794	3	1.0	33,000	31,800	32,350	1,[illegible]
Du Pont's N. V., lot 5	1.825	2	1,809	1,795	1,802	14	7.0	34,400	32,900	33,500	1,500
German brown	1.863	1	....	.....	1,711	....	......	......	.	31,400	..

REMARKS.—For most of the rounds the pressure was indicated by two crusher gauges seated in the mushroom head. The indications of the two gauges differed considerably in several of the rounds. The mean difference in the reading of the gauges for 33 rounds was 769 pounds; the maximum difference was 2,400 pounds.

TABLE 2.—*Table showing the velocities and pressures obtained with the proof samples and different numbers representing different methods of blending of lots* 1, 2, *and* 3, *of N. V. powder.*

[Charge, 265 pounds; weight of projectile, 800 pounds; density of loading, 0.827.]

	Mean initial velocity.			Mean indicated pressure.		
	N. V., lot 1.	N. V., lot 2.	N. V., lot 3.	N. V., lot 1, pounds per square inch.	N. V., lot 2, pounds per square inch.	N. V., lot 3, pounds per square inch.
	Feet.	*Feet.*	*Feet.*			
Sample for proof	1,758	1,756	1,726	25,040	28,025	[illegible]
No. 1	(*)	1,688	1,701	(*)	25,210	[illegible]
No. 2	1,731	1,764	1,710	26,380	26,075	[illegible]
No. 3	1,780	1,755	1,702	30,100	30,025	[illegible]

*Not fired with 800-pound projectiles.

POWDERS FOR 8-INCH B. L. STEEL RIFLE.

The following varieties of brown prismatic powder have been furnished for trial in the 8-inch experimental rifle:

Powder.	Density.
German brown	1.858
Du Pont's P. A	1.825
Du Pont's P. I	1.838
Du Pont's P. K	1.830
Du Pont's P. N	1.840

the size and form of grain being the same as for the powders used in the 12-inch cast-iron rifle.

The following results were obtained using 100-pound charges and projectiles weighing 235 pounds, and density of loading 0.891:

Powder.	Initial velocity.	Maximum (A plug).	Pressure (B plug).
	Feet.		
German brown	1,944	32,400	31,900
Du Pont's P. A	1,940	32,700	33,200
Du Pont's P. I	1,756	18,300	22,475
Du Pont's P. K	2,028	37,425	37,900

Du Pont's P. A. is about equivalent in ballistic properties to the German brown powder. P. I. is too slow a powder for charges of 100 pounds. The capacity of the chamber in the 8-inch rifle admits of increasing the charge to about 120 pounds; with charges of this size powder similar to P. I. might give good results.

P. K. powder gave such high pressure that it was not fired with the heaviest projectile.

The results obtained with 100-pound charges and the heaviest projectile weighing 286 pounds and density of loading 0.89, are given below:

Powder.	Initial velocity.	Maximum (A plug).	Pressure (B plug).
	Feet.	*Pounds.*	*Pounds.*
German Brown	1,795	33,800	31,800
Du Pont's P. A	1,820	36,200	34,700
Du Pont's P. I	1,710	26,750	27,100

The manufacture of brown prismatic powder for 8 and 12 inch guns is still in its experimental stage, and will not assume a definite shape until more extended trials have been made. The uncertainties attending its production are being carefully studied by the American makers, and it is hoped that, by contemplated improvements in the plant and method of manufacture, they may in the near future be practically eliminated, and that the standard varieties determined upon for the different calibers may be reproduced without difficulty.

Both the German and American brown powders show great sensitiveness to moisture due to the hygroscopic qualities of the coal used. This is only partially counteracted by the high density given the grain, and unusual precautions are required in the packing and storage of these powders to preserve them intact.

The Messrs. Du Pont report, as the result of their experiments, that both the German and American powders absorb moisture rapidly. When submitted to ordinary atmospheric exposure they show curves of absorption which are exactly alike. The American powder, however, becomes coated with mold, while the German shows only a slight tendency in that direction.

The prismatic powder sent to the proving ground was packed in unsealed wooden boxes, awaiting the completion of suitable metallic cases, and a large quantity of it has become mildewed while in storage. How far this will affect its ballistic properties remains to be determined by future experiment, but it points to the necessity of providing air-tight metallic cases or boxes with air-tight metallic linings for the storage of all brown prismatic powders.

POWDERS FOR 12-INCH M. L. MORTAR.

Various lots of experimental powders of different forms of grain, granulation, and density have been tested in this gun. The following table gives a summary of the lots tried and the results obtained with full charges of 52 pounds and a 610-pound shell, with density of loading, 0.854.

Designation of the powder.	Form of the grain.	Number of grains to the pound.	Density.	Number of rounds considered.	Mean initial velocity.	Mean indicated pressure.
					Feet.	*Pounds per square inch.*
M. W	Hexagonal	72	1.725	1	1,019	[illegible]
O. B	Sphero-hexagonal	123	1.725	2	967	23,[illegible]
O. C	....do	123	1.750	2	942	19,[illegible]
O. U	....do	100	1.725	2	1,015	30,[illegible]
O. V	....do	100	1.750	3	985	25,[illegible]
O. V., No. 1	....do	100	1.750	4	998	26,[illegible]
O. V., No. 2	....do	100	1.750	3	1,005	22,[illegible]
P. G	....do	100	1.775	3	976	24,[illegible]
O. X	....do	100	1.795	3	960	18,[illegible]

A powder giving with full charges a velocity of about 985 feet and a maximum pressure of 26,000 pounds was required. The hexagonal powder M. W. being too violent, the sphero-hexagonal powders O. B. and O. C., with a granulation of 123 to the pound, were tried, the O. B. giving the desired results. Later, with the idea of introducing greater uniformity in the different lots, the granulation was changed to 100 to the pound and samples of different densities tested. Lots of 6,000 pounds each of O. V. No. 1 and P. G. powders were accepted and are now on hand at the proving-ground.

The sample of powder marked O. X., while giving a little lower velocity than required, is a very promising variety of powder, and may be developed by future experiments with better results than any so far obtained. The maximum pressure given by this powder is so low that, the indications are, that had the density been a little less, the required velocity would have been obtained with a pressure considerably lower than that given by any of the lots so far accepted.

It appears to be, in comparison with the other powders, more progressive in its action, that is, it gives a lower maximum pressure for a given mean pressure throughout the bore, or, conversely, for a given maximum pressure it will give a higher mean pressure throughout the bore.

For the reduced charge of 26 pounds a powder was required giving a velocity of 650 feet and a pressure not exceeding 13,000 pounds with a 610-pound shell.

The hexagonal powder M. V., granulation 72, density 1.700, gave a muzzle velocity of 664 feet, with a maximum pressure of about 12,000 pounds. This was deemed satisfactory, and lots amounting to 4,500 pounds were accepted for experimental firing.

APPENDIX 30.

REPORT ON THE FABRICATION OF 3.2-INCH STEEL B. L. FIELD-GUNS.

BY MAJ. F. H. PARKER, ORDNANCE DEPARTMENT.

(2 plates.)

Orders for making five of these guns were dated May 13, 1885, with the information that the forgings would be supplied from the Midvale Works in early June, 1885, but these expectations as to time were not realized, and the first forgings were received here December 10, 1885. The second lot on December 17, 1885, and the third delivery was made January 16, 1886, others on January 30, March 22, April 29, and finally the last, which was the fifth tube, came as late as June 10, 1886.

This of course delayed the completion of the guns, all five of which would easily have been completed during the year if the forgings had been received during the winter. As it was, about five or six weeks' work remained at the end of June to finish the five guns; the condition of the work being on June 30 as follows, viz:

Three guns completed, except three or four hours required to finish fitting breech mechanism of third gun.

The fourth gun shrunk together and all its parts nearly finished. The fifth gun ready to shrink except the tube, which was bored and partly turned. Its other parts are nearly finished, excepting base-ring, which is to be made.

The delay in receipt of the forgings gave an opportunity to make convenient arrangements for the work of finishing and assembling both the field and siege guns. The machinery needed for the work, some of which was newly purchased, was assembled together in one of the large shops which had formerly been used as a wood worker's shop, and this was set aside for a gun-shop. A shrinking pit and crane were erected in convenient proximity, and water and gas supplied for use in assembling the gun.

DESCRIPTION OF THE GUN.

The Annual Report of the Chief of Ordnance for 1884, Appendix 33, contains a full description of the experimental 3.2-inch gun, which is the prototype of these guns now being made for service.

Slight changes have, however, been made from that model. It is somewhat heavier, which is occasioned by a change in the outline, principally in rear of the trunnions, straight lines having been substituted for curved, the muzzle band being reduced to a slight swell and a sight mass having been left on the right rim base. Drawings herewith show the design, and the inspection reports with this report give all the dimensions and weights.

The forgings, consisting of a tube, jacket, sleeve, trunnion-hoop, base-ring, key-ring, breech-block, obturator stem, lever handle, carrier-ring, gas-check ring, and nuts, were roughed out at Midvale, oiled, tempered,

and annealed before delivery. Some small parts, such as pins and stops and springs, were supplied at this arsenal.

Test pieces from each forging were sent here for test, and the forgings were received or rejected from the results of the test.

The specifications required the metal to exhibit the following qualities, viz:

	E. L.	T. S.	Elongation.
	Pounds.	*Pounds.*	*Per cent.*
Tube	42,000	88,000	20
Jacket	50,000	95,000	18
Trunnion-hoop..	48,000	95,000	15

The sleeve, breech-block, base-ring, and other small parts to have the same qualities as the jacket.

The gun consists of a central tube, the greatest exterior diameter of which is 6″ and the minimum near the muzzle, 4″.60, length 85″.2; a jacket with maximum diameter of 9″.56 and length 25″.9, which is shrunk over the rear part of the tube, a shoulder of which prevents the latter from going forward: the rear end of the tube abuts against the base-ring, which is screwed inside of the jacket at the rear end which projects beyond the tube; the French or slotted-screw breech-block works in this base-ring. In front of the jacket, and bound to it by an overlapping locking joint, is the trunnion-hoop shrunk on to the tube. Its width between rim bases is 9″.5 and its length 8″.8. In front of the trunnion-hoop, and bearing close against it, is the sleeve, shrunk on to the tube, maximum diameter 6″.8 minimum 6″.6, length 13″.3, and in front of that the key ring, which is screwed on to the tube and firmly against the sleeve, diameter 6″.5, length 3″.0. In front of that the tube is unsupported for a length of 38″.7 to the muzzle. All the members are thus bound securely together by shoulders and screw-threads in a manner which presents no greater difficulty of construction than the shrinkage of plain superposed cylinders usually offers.

All the guns so far made here have been provided with the Freyre (Spanish) gas check, which was found to be effective in the experimental gun, but the length of space in rear of the chamber permits of the use of the De Bange (French) gas check, which is equally effective, and is to be used in some of the guns.

The powder chamber is elliptical; the shot chamber, composed of two inclines and a straight surface, furnishes a place for the rear banded portion of the shot to rest, the forward part extending into the grooved portion of the bore, the band bringing up against the lands, which are beveled at their rear termination.

The venting is radial at the middle part of the chamber.

The rifling is uniform, with a twist of 1 turn in 30 calibers, or an angle of 6 degrees. There are 24 grooves and lands.

The total length of the piece is 90″.7; its weight 803 pounds; its preponderance at end of breech 57 pounds.

THE BREECH MECHANISM.

The breech-block, 6″.45 long by 4″.47 in diameter, is threaded and slotted, three sections being plain and three with threads. The base ring in which it works is threaded and slotted correspondingly. One-sixth of a turn, therefore, serves to lock or unlock the block when in its place. The stem of the obturator passes through the center of the block. The last or rearmost thread on the block is not cut away, which

serves the purpose of closing the rear face of the breech against dirt and weather, and as a stop for the block when it is pressed into its place. The grooves for stops are cut in two of the blanks, and are extended circumferentially for the stops to move in when the block is turned.

A narrow longitudinal and circumferential groove, deepening towards the ends, is also made for the head of the latch-pin to move in, which pin passes through the carrier-ring into a recess in the jacket and automatically locks and unlocks the ring at different stages of opening and shutting the breech. The lever handle for turning the block and the bronze handle for withdrawing it are fastened to its rear end.

The carrier-ring carries the block when it is withdrawn and swung out of place to permit of loading. It is but 1″.2 thick, and when it is closed against the end of the base-ring it fills the space between the jacket and the block. The latch-pin and its spring is held in this ring.

The Freyre obturator terminates in a head in front of the breech-block, shaped like a truncated cone slightly dished in its face. A gas-check ring of highly elastic steel, formed to fit the cone surface on the inside but nearly cylindrical on the outside where it fits the seat inside the bore, fits around this head and rests against the breech-block.

The head is not in contact with the block but nearly so, and the distance can be increased or diminished by the nuts screwed on to the rear end of the spindle. A strong spring intervenes which keeps the head away from the face of the block except during the great pressure of the powder gases, when by being pressed home it expands the elastic ring against its seat, which effectually cuts off all escape of gas. When the pressure is removed, the spring forces the head forward and the ring is allowed to contract. The expansion of the gas-check is thus rendered independent of the amount of pressure, and can be regulated to suit the character of the steel in the gas-check ring.

The requirements in the operation of the breech mechanism are security, facility of movement, and perfect obturation. This requires—

(1) That the block shall not be allowed to turn out of the threads when in place for firing. Which is secured by the end of the lever-handle fitting into a recess in the jacket when it is down in place and its head into a recess in the carrier-ring.

(2) That when the block is turned ready to be withdrawn, the carrier-ring shall be locked in place. This is accomplished automatically by the pushing out of the latch-pin into the jacket occasioned by the shallowing of the groove in the block in which the end of the pin moves as the block is turned.

(3) That when the block is withdrawn the carrier-ring shall be unlocked ready to swing out of the way with the block. This is also automatically performed by deepening the longitudinal groove in which the head of the latch-pin now moves until at the termination of the movement it is in a depression, the latch-pin spring having withdrawn it from the recess in the jacket.

(4) That in swinging the block and ring closed, the former shall not be pushed through the latter until it is completely closed and in the axis of the bore. Owing to the depth and shape of the depression at the end of the groove, the head of the latch-pin holds the block and ring together, and accomplishes the desired end.

(5) That when the block is being pushed into its place the carrier-ring shall become locked, and as it is turned so that the screw-threads engage in those of the base-ring, the ring shall become unlocked, in order that no strain can possibly be thrown on it. This being the reverse of what is accomplished in opening the breech, it naturally takes

place by the movement of the head of the latch-pin up the inclined longitudinal groove and down the inclined circumferential one.

The block is turned to the left by the lever, which is first raised up nearly vertical out of its recess. After the block is turned the lever is brought smartly down, when the cam-shaped head bears against the carrier-ring and forces the block to the rear slightly, freeing the gas-check from its seat. The bronze handle then serves to draw the block through the ring and to swing both clear of the bore.

When the lever is completely closed down in its recess, the gun is ready to fire and not before. Precaution should, therefore, be taken in this respect.

WORK ON THE DIFFERENT PARTS.

The tubes were first bored from the forging to within 0″.05 of the finished bore, including the powder-chamber. They were then rough-turned their whole length and finished as far forward as front end of sleeve to the proper diameters. The average time of this work for each tube was 189¾ hours. This was occasioned by the eccentricity and irregularity of the rough-boring.

The skill and knowledge brought by experience reduced the time as the work proceeded.

The jackets were bored and finished inside to their proper diameters and then rough-turned on the outside the entire length to 0″.10 of the finished dimensions. After shrinking on the tube, the shoulder for the reception of the trunnion-band was finished. All this for each jacket averaged 116¼ hours' work.

The trunnion-hoops were first bored to finished dimensions and then finished on the outside except chipping around rimbases and fine filing. The average time for each hoop was 175¼ hours' work. The sleeves were finish-bored, and rough-turned on the outside to 0.10″ of the finished dimensions. Average time per sleeve, 28¼ hours.

The key-rings were bored out and threaded and outside turned nearly to finished dimensions. Number of hours' work, 24 each.

The base-rings were fine-bored, threaded, and slotted, and finish-turned and threaded on the outside. Number of hours' work, 65¼ each.

The carrier rings were bored, faced up, hinge planed out, outside shaped, latch-pin fitted, guide blocks made and fitted in position, and recess for cam end of lever milled out, latch-pin, hinge-pin, and all parts made. Number of hours' work, 140 each.

The breech-blocks were bored for spindle, turned and threaded, and slotted on outside; guide-grooves for stops and inclined grooves planed and lugs finished. Number of hours' work, 179½ each.

The spindles, springs, and nuts required 42 hours' work to finish each.

The gas-check rings were ground to obturator heads and to seats in the bores. A clearance between gas-check and seat of 0″.004 was left. The clearance between face of breech-block and obturator head was 0″.012. Number of hours for each, 36.

The lever-handles and pins required 32 hours' work to complete each one.

The bronze handles and screws required to cast and finish 17 hours' each.

ASSEMBLING THE GUN.

The jacket, trunnion-hoop, and sleeve were successively heated by a wood-fire, built over the shrinking-pit. The tube, or the tube and part already shrunk on, was hung vertically from the overhead crane out of

the way at one side of the fire. As soon as the member in the fire had expanded sufficiently the fire was dropped into the pit and extinguished, the hanging part moved along and lowered vertically into its place through the part which was to be shrunk onto it. Two rods on the outside of the heated member which passed through a cross-head, and which were at the same time heated, contracted upon being cooled, held the parts closely together, and assisted in preventing them from shrinking apart. The water-ring and gas-ring were applied, to cause the outside parts to contract first at the upper or rear end. The measurements of expansion were made with pointed gauges, which could be set at the desired length. When they passed through, the expansion was sufficient.

Plates and a full description of this method and apparatus used is given in Chief of Ordnance's Report of 1884, Appendix 33.

The shrinkage prescribed was 0″.00135 per inch of diameter, but for the first two guns a shrinkage of 0″.0015 was used, the same as that of the experimental gun made in 1884. This variation in the relative shrinkage made hardly any difference in the actual shrinkage of these small guns.

It was intended that the expansion of the outside parts should not exceed 0.02 of an inch over corresponding diameter of the tube, but this had to be violated in the trunnion-ring, owing to the tapered shape of the shoulder that locks into the jacket.

The heating often showed a dull red before sufficient expansion resulted.

The number of men employed in shrinking was four, and the following table (1) shows the length of time required to heat the different parts of the four guns already assembled and the amount of expansion.

Tables 2 and 3 give full data as to the amount of shrinkage and its effects.

TABLE 1.—*Guns Nos. 1, 2, 3, and 4.—Time required to heat parts and amount of expansion.*

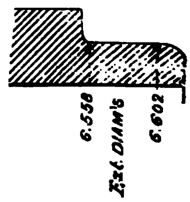
Part.	First gun.		Second gun.	
	Time required.	Amount of expansion.	Time required.	Amount of expansion.
		Inches.		*Inches.*
Jacket	1 hour and 20 minutes.	Large diameter 0.04 Small diameter 0.02	40 minutes.	0.029
Trunnion-hoop	1 hour and 5 minutes.	Bore 0.042 Lip of shoulder 0.061	40 minutes.	Bore 0.041 Lip of shoulder 0.062
Sleeve	15 minutes	0.028	20 minutes.	0.025

Part.	Third gun.		Fourth gun.	
	Time required.	Amount of expansion.	Time required.	Amount of expansion.
		Inches.		*Inches.*
Jacket	40 minutes	0.02	1 hour and 10 minutes.	0.025
Trunnion-hoop	40 minutes	Bore 0.042 Lip of shoulder. 0.067	1 hour and 20 minutes.	Bore 0.040 Lip of shoulder. 0.056
Sleeve	15 minutes	0.025	15 minutes.	0.022

TABLE 2.—*Actual measurement of exterior of tube and interior of jacket, sleeve, and trunnion-band before shrinkage.*

GUN 1.

Distance from rear end of jacket.	Exterior diameter of tube.	Interior diameter of jacket, trunnion-ring, and sleeve	Difference of diameters, actual shrinkage.	Prescribed shrinkage.	Difference.	Remarks.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	
0	......	5.998	......	......	.	
2	......	5.998	...	......	......	
4	......	5.998	.		......	
6	6.006	5.998	.008	.009	—.001	0''.5 from end of tube=6'' from end of j ck.
8	6.007	5.999	.008	.009	—.001	
10	6.008	5.999	.009	.009	0	
12	6.008	5.999	.009	.009	0	Jacket.
14	6.008	5.999	.009	.009	0	
16	6.008	5.999	.009	.009	0	
18	6.008	5.399	.009	.009	0	
20	6.008	5.999	.009	.009	0	
22	6.007	5.998	.009	.009	0	
24	5.605	5.598	.007	.008	—.001	
26	5.606	5.598	.008	.008	0	
27.15	5.605	{ 5.597 / 5.598 }	.008	.008	0	
29.15	5.606	{ 5.597 / 5.598 }	.008	.008	0	
31.15	5.606	{ 5.597 / 5.597 }	.009	.008	+.001	
33.15	5.607	{ 5.597 / 5.597 }	.010	.008	+.002	Trunnion-band.
34.70	5.606	5.600	.006	.008	—.002	
36.70	5.607	5.600	.007	.008	—.001	
38.70	5.607	5.599	.008	.008	0	
40.70	5.607	5.599	.008	.008	0	Sleeve.
42.70	5.607	5.598	.009	.008	+.001	
44.70	5.607	5.598	.009	.008	+.001	
46.70	5.607	5.599	.008	.008	0	



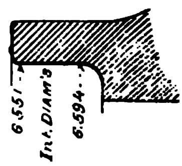
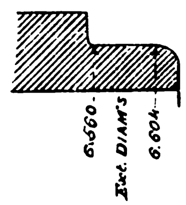


TABLE 2.—*Actual measurement of exterior of tube and interior of jacket, &c.*—Continued.

GUN 2.

Distance from rear end of jacket.	Exterior diameter of tube.	Interior diameter of jacket, trunnion-ring, and sleeve.	Difference of diameters, actual shrinkage.	Prescribed shrinkage.	Difference.	Remarks.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	
2	....	5.999	....	.009	.....	6″ from end of jacket = 0″.5 from end of tube.
4	.....	5.998	....	.009	.....	
6	6.008 / 6.008	5.999	.009	.009	0	
8	6.009 / 6.008	6.000	.009	.009	0	
10	6.009 / 6.010	6.000	.009	.009	0	
12	6.009 / 6.010	6.000	.009	.009	0	
14	6.009 / 6.010	5.999	.009	.009	0	Jacket.
16	6.009 / 6.010	6.000	.009	.009	0	
18	6.009 / 6.010	6.000	.009	.009	0	
20	6.008 / 6.010	5.999	.009	.009	0	
22	6.009 / 6.008	5.999	.009	.009	0	
24	5.608 / 5.608	5.999	.009	.008	+.001	
26	5.608 / 5.608	5.999	.009	.008	+.001	
27.15	5.608 / 5.608	5.598 / 5.599	.009	.008	+.001	
29.15	5.608 / 5.608	5.599 / 5.599	.009	.008	+.001	
31.15	5.608 / 5.668	5.599 / 5.598	.009	.008	+.001	Trunnion-band.
33.15	5.608 / 5.608	5.599 / 5.598	.009	.008	+.001	
34.70	5.608 / 5.608	5.600 / 5.600	.008	.008	0	
36.70	5.608 / 5.607	5.599 / 5.599	.008	.008	0	
38.70	5.608 / 5.607	5.599 / 5.599	.008	.008	0	
40.70	5.608 / 5.607	5.599 / 5.599	.008	.008	0	Sleeve.
42.70	5.608 / 5.607	5.599 / 5.599	.008	.008	0	
44.70	5.608 / 5.607	5.599 / 5.599	.008	.008	0	
46.70	5.608 / 5.607	5.599 / 5.599	.008	.008	0	



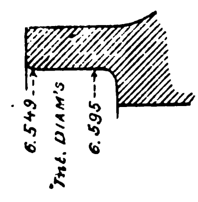
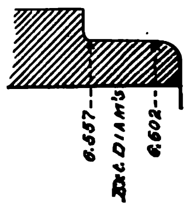


TABLE 2.—*Actual measurement of exterior of tube and interior of jacket, &c.*—**Continued.**

GUN 3.

Distance from rear end of jacket.	Exterior diameter of tube.	Interior diameter of jacket, trunnion-ring, and sleeve.	Difference of diameters, actual shrinkage.	Prescribed shrinkage.	Difference.	Remarks.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	
0	...	6.000 6.000	....	.0081	....	March 12, order received changing shrinkages from 0″.009 to 0″.0081 and 0″.008 to 0″.0075, taking effect on guns Nos. 3, 4, and 5, Nos. 1 and 2 having been finished.
2	......	5.998 5.999	....	.0081	....	
4	....	5.998 5.999	... ..	.0081	....	
6	6.007 6.007	5.998 5.999	.008	.0081	—.0001	=0″.5 from end of tube.
8	6.007 6.007	5.999 5.999	.008	.0081	—.0001	
10	6.007 6.007	5.999 5.999	.008	.0081	—.0001	
12	6.007 6.007	5.998 5.999	.008	.0081	—.0001	
14	6.007 6.007	5.998 5.909	.008	.0081	—.0001	Jacket.
16	6.007 6.007	5.998 5.989	.008	.0081	—.0001	
18	6.007 6.007	5.998 5.999	.008	.0081	—.0001	
20	6.007 6.007	5.998 5.999	.008	.0081	—.0001	
22	6.007 6.007	5.997 5.998	.008	.0081	—.0001	
24	5.606 5.606	5.599 5.599	.007	.0075	—.0005	
26	5.606 5.606	5.598 5.599	.007	.0075	—.0005	
27.15	5.606 5.606	5.599 5.599	.007	.0075	—.0006	
29.15	5.606 5.606	5.599 5.590	.007	.0075	—.0005	
31.15	5.606 5.606	5.599 5.599	.007	.0075	—.0005	
33.15	5.606 5.606	5.599 5.599	.007	.0075	—.0005	Trunnion-band.
34.70	5.606 5.606	5.599 5.599	.007	.0075	—.0005	
36.70	5.606 5.606	5.599 5.599	.007	.0075	—.0005	
38.70	5.606 5.606	5.599 5.599	.007	.0075	—.0005	
40.70	5.606 5.606	5.599 5.599	.007	.0075	—.0005	Sleeve.
42.70	5.606 5.606	5.598 5.598	.007	.0075	—.0005	
44.70	5.606 5.606	5.598 5.598	.008	.0075	+.0005	
46.70	5.606 5.606	5.598 5.598	.008	.0075	+.0005	



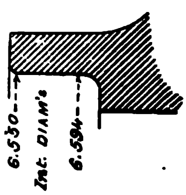
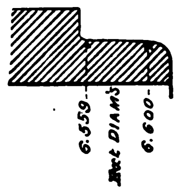


TABLE 2.—*Actual measurement of exterior of tube and interior of jacket, &c.*—Continued.

GUN 4.

Distance from rear end of jacket.	Exterior diameter of tube.	Interior diameter of jacket, trunnion-ring, and sleeve.	Difference of diameters, actual shrinkage.	Prescribed shrinkage.	Difference.	Remarks.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	
0	....	....	....	.0081	....	Jacket.
2	....	5.998 5.998	....	.0081	....	
4	....	5.998 5.998	....	.0081	....	
6	6.007 6.007	5.998 5.998	.009	.0081	+.0009	=0″.5 from end of tube.
8	6.007 6.007	6.000 6.000	.007	.0081	—.0011	
10	6.007 6.007	6.000 5.999	.0075	.0081	—.0006	
12	6.007 6.007	6.000 6.000	.007	.0081	—.0011	
14	6.007 6.007	5.999 5.999	.008	.0081	—.0001	
16	6.007 6.007	5.999 5.999	.008	.0081	—.0001	
18	6.007 6.007	5.999 5.998	.0085	.0081	+.0004	
20	6.007 6.007	5.999 5.998	.0085	.0081	+.0004	
22	6.007 6.007	5.998 5.997	.0095	.0081	+.0014	
24	5.604 5.604	5.598 5.598	.006	.0075	—.0015	
26	5.604 5.604	5.597 5.597	.007	.0075	—.0005	
27.15	5.604 5.604	5.597 5.597	.007	.0075	—.0005	Trunnion-band.
29.15	5.604 5.604	5.597 5.597	.007	.0075	—.0005	
31.15	5.604 5.604	5.597 5.597	.007	.0075	—.0005	
33.15	5.604 5.604	5.596 5.596	.008	.0075	+.0005	
34.70	5.606 5.606	5.600 5.600	.006	.0075	—.0015	Sleeve.
36.70	5.606 5.606	5.599 5.599	.007	.0075	—.0005	
38.70	5.606 5.606	5.600 5.599	.0065	.0075	—.0010	
40.70	5.606 5.606	5.599 5.599	.007	.0075	—.0005	
42.70	5.606 5.606	5.599 5.599	.007	.0075	—.0005	
44.70	5.606 5.606	5.599 5.599	.007	.0075	—.0005	
46.70	5.606 5.606	5.600 5.600	.006	.0075	—.0015	



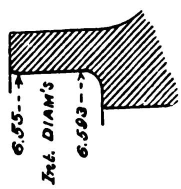


TABLE 3.—*Measurements of tube bore before and after shrinkage.*

GUN 1.

[Shoulder 18 inches from rear end. Trunnion-band begins 21.65 inches. Trunnion-band ends 29.20 inches. Sleeve ends 42.50 inches.]

Distance from rear end.	Diameters before shrinkage.	Diameters through plane of trunnions after shrinkage.	Diameters perpendicular to plane of trunnions after shrinkage.	Actual contractions. Through trunnions.	Actual contractions. Perpendicular to trunnions.	Remarks.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	
....	3.348	3.341	3.341	.007	.007	For a distance of 1".80 from end.
7	3.751	3.749	3.749	.005	.005	Maximum diameter of powder-chamber.
13	3.154 3.154	3.148	3.148	.006	.006	Jacket, rear of shoulder.
15	3.154 3.154	3.149	3.149	.005	.005	
17	3.154 3.154	3.150	3.149	.004	.005	
19	3.154 3.154	3.151	3.149	.003	.005	
21	3.154 3.154	3.149	3.149	.005	.005	Jacket, front of shoulder.
23	3.154 3.154	3.148	3.149	.006	.005	
25	3.154 3.154	3.147	3.149	.007	.005	
27	3.154 3.154	3.149	3.149	.005	.005	Trunnion-band.
29	3.154 3.154	3.150	3.150	.004	.004	
31	3.154 3.154	3.151	3.150	.003	.004	
33	3.154 3.154	3.151	3.151	.003	.003	
35	3.154 3.154	3.151	3.151	.003	.003	
37	3.154 3.154	3.150	3.150	.004	.004	
39	3.154 3.154	3.150	3.150	.004	.004	
41	3.154 3.154	3.150	3.150	.004	.004	
43	3.154 3.154	3.151	3.150	.003	.004	End of sleeve 42.50.
45	3.154 3.154	3.152	3.151	.002	.003	
47	3.154 3.154	3.152	3.152	.002	.002	Sleeve.
49	3.153 3.154	3.152	3.152	.001	.002	
51	3.153 3.153	3.152	3.152	.001	.001	
53	3.154 3.153	3.152	3.152	.002	.001	
55	3.154 3.154	3.152	3.152	.002	.002	
57	3.153 3.153	3.152	3.152	.001	.001	
59	3.153 3.154	3.152	3.152	.001	.002	
61	3.154 3.154	3.152	3.152	.002	.002	
63	3.154 3.154	3.152	3.152	.002	.002	At distance of 75" the size of the bore remains the same, 3".154.

TABLE 3.—*Measurements of tube bore before and after shrinkage*—Continued.

GUN 2.

Distance from rear end.	Diameter before shrinkage.	Diameters through plane of trunnions after shrinkage.	Diameters perpendicular to plane of trunnions after shrinkage.	Actual contractions. Through trunnions.	Actual contractions. Perpendicular to trunnions.	Remarks.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	
....	3.346	3.337	3.337	.009	.009	For a distance of 1".80 from end.
7	3.753	3.748	3.748	.005	.005	Maximum diameter powder-chamber.
14	3.152 3.152	3.147	3.148	.005	.004	Jacket, rear of shoulder.
15	3.152 3.152	3.148	3.148	.004	.004	
17	3.152 3.153	3.148	3.148	.004	.005	
19	3.153 3.152	3.148	3.148	.005	.004	Jacket, front of shoulder.
21	3.153 3.152	3.148	3.148	.005	.004	
23	3.152 3.152	3.147	3.148	.005	.004	Trunnion-band.
25	3.152 3.152	3.147	3.149	.005	.003	
27	3.152 3.152	3.148	3.148	.004	.004	
29	3.152 3.152	3.149	3.149	.003	.003	
31	3.152 3.152	3.149	3.149	.003	.003	Sleeve.
33	3.152 3.152	3.149	3.149	.003	.003	
35	3.152 3.152	3.149	3.149	.003	.003	
37	3.152 3.152	3.149	3.149	.003	.003	
39	3.152 3.152	3.149	3.149	.003	.003	
41	3.152 3.152	3.149	3.149	.003	.003	
43	3.152 3.152	3.150	3.150	.002	.002	
45	3.153 3.152	3.150	3.151	.003	.001	
47	3.153 3.152	3.150	3.151	.003	.001	
49	3.152 3.152	3.150	3.151	.002	.001	
51	3.152 3.152	3.151	3.151	.001	.001	
53	3.152 3.152	3.152	3.152	0	0	
55	3.153 3.152	3.152	3.152	.001	0	
57	3.153 3.153	3.152	3.152	.001	.001	
59	3.153 3.153	3.152	3.152	.001	.001	
61	3.153 [illegible]	3.152	3.152	.001	.001	
63	3.152 3.152	3.152	3.152	0	0	At distance of 73" no variation from original bore.

TABLE 3.—*Measurement of tube bore before and after shrinkage*—Continued.

GUN 3.

Distance from rear end.	Diameters before shrinkage.	Diameters through plane of trunnions after shrinkage.	Diameters perpendicular to plane of trunnions after shrinkage.	Actual contractions.		Remarks.
				Through trunnions.	Perpendicular to trunnions.	
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	
....	3.345	3.340	3.340	.005	.005	A distance of 1″.80 from end.
7	3.75	3.744	3.744	.006	.006	Maximum diameter of powder-chamber.
14	3.154 3.154	3.148	3.148	.006	.006	
15	3.153 3.154	3.149	3.149	.004	.005	Jacket, rear of shoulder.
17	3.153 3.154	3.149	3.149	.004	.005	
19	3.153 3.154	3.149	3.150	.004	.004	
21	3.153 3.153	3.148	3.150	.005	.003	Jacket, front of shoulder.
23	3.153 3.153	3.148	3.150	.005	.003	
25	3.153 3.153	3.148	3.150	.005	.003	
27	3.153 3.153	3.148	3.149	.005	.004	Trunnion-band.
29	3.153 3.153	3.149	3.149	.004	.004	
31	3.153 3.153	3.150	3.150	.003	.003	
33	3.153 3.153	3.150	3.150	.003	.003	
35	3.153 3.153	3.149	3.150	.004	.003	
37	3.153 3.153	3.149	3.150	.004	.003	
39	3.153 3.153	3.149	3.151	.004	.002	
41	3.153 3.153	3.149	3.151	.004	.002	
43	3.153 3.153	3.149	3.151	.004	.002	
45	3.153 3.153	3.151	3.152	.002	.001	
47	3.153 3.153	3.151	3.152	.002	.001	Sleeve.
49	3.153 3.153	3.152	3.152	.001	.001	
51	3.153 3.153	3.152	3.152	.001	.001	
53	3.153 3.153	3.152	3.152	.001	.001	
55	3.153 3.153	3.152	3.152	.001	.001	
57	3.153 3.153	3.152	3.152	.001	.001	
59	3.153 3.153	3.152	3.152	.001	.001	
61	3.153 3.153	3.152	3.152	.001	.001	
63	3.153 3.153	3.152	3.152	.001	.001	At 75 inches from rear, size of bore is 3″.153, as before shrinking.

TABLE 3.—*Measurement of tube bore before and after shrinkage*—Continued.

GUN 4.

Distance from rear end.	Diameters before shrinkage.	Diameters through plane of trunnions after shrinkage.	Diameters perpendicular to plane of trunnions after shrinkage.	Actual contractions. Through trunnions.	Actual contractions. Perpendicular to trunnions.	Remarks.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	
7	3.748	3.745	3.745	.003	.003	Maximum diameter of powder-chamber.
13	3.147 3.147	3.144	3.144	.003	.003	Jacket, rear of shoulder.
15	3.147 3.147	3.144	3.144	.003	.003	
17	3.147 3.147	3.145	3.144	.002	.003	
19	3.147 3.147	3.144	3.144	.003	.003	Jacket, front of shoulder.
21	3.147 3.147	3.143	3.144	.004	.003	
23	3.147 3.147	3.143	3.145	.004	.002	Trunnion-band.
25	3.147 3.147	3.144	3.144	.003	.003	
27	3.147 3.147	3.145	3.144	.002	.003	
29	3.147 3.147	3.146	3.144	.001	.003	
31	3.147 3.147	3.146	3.145	.001	.002	Sleeve.
33	3.147 3.147	3.146	3.145	.001	.002	
35	3.147 3.147	3.145	3.146	.002	.001	
37	3.147 3.147	3.144	3.146	.003	.001	
39	3.147 3.147	3.145	3.146	.002	.001	
41	3.147 3.147	3.146	3.147	.001	0	
43	3.147 3.147	3.147	3.147	0	0	
45	3.147 3.147	3.147	3.147	0	0	
47	3.147 3.147	3.147	3.147	0	0	
49	3.147 3.147	3.147	3.147	0	0	
51	3.147 3.147	3.147	3.147	0	0	
53	3.147 3.147	3.147	3.147	0	0	
55	3.147 3.147	3.147	3.147	0	0	
57	3.147 3.147	3.147	3.147	0	0	
59	3.147 3.147	3.147	3.147	0	0	
61	3.147 3.147	3.147	3.147	0	0	
63	3.147 3.147	3.147	3.147	0	0	

After having been shrunk together the guns were finish-bored, which required 24 hours' work each; rifled, which required 66 hours; chambering, 77½ hours; threading for base-ring and assembling base-ring, 75⅔ hours; finish turning chase sleeve and jacket and chipping and filing around rim bases, 211½ hours; slotting and drilling for hinge, 29½ hours; making vent-piece, drilling and putting in gun, 30½ hours; assembling and fitting breech mechanism, 79 hours.

The guns were star gauged before and after rifling. The following tabl (4) gives the results:

TABLE 4.—*Star gauge of bore before and after rifling.*

GUN 1.

Distance from rear.	Bore. Perpendicular to trunnions.	Bore. Through axis of trunnions.	Rifling bottom of grooves.	Distance from rear.	Bore. Perpendicular to trunnions.	Bore. Through axis of trunnions.	Rifling bottom of grooves.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
19	3.203	3.203	3.301	55	3.203	3.203	3.301
21	3.203	3.203	3.301	57	3.203	3.203	3.301
23	3.203	3.203	3.301	59	3.203	3.204	3.301
25	3.203	3.203	3.301	61	3.203	3.204	3.301
27	3.203	3.203	3.301	63	3.203	3.203	3.301
29	3.203	3.203	3.301	65	3.203	3.203	3.301
31	3.204	3.203	3.301	67	3.203	3.203	3.301
33	3.203	3.203	3.301	69	3.203	3.204	3.301
35	3.204	3.203	3.301	71	3.203	3.204	3.301
37	3.204	3.203	3.301	73	3.203	3.204	3.301
39	3.203	3.203	3.301	75	3.204	3.204	3.301
41	3.204	3.203	3.301	77	3.204	3.204	3.301
43	3.204	3.203	3.301	79	3.204	3.204	3.301
45	3.203	3.203	3.301	81	3.204	3.204	3.301
47	3.203	3.203	3.301	83	3.204	3.204	3.301
49	3.203	3.204	3.301	85	3.204	3.204	3.301
51	3.203	3.203	3.301	87	3.204	3.204	3.301
53	3.203	3.203	3.301	89	3.204	3.204	3.301

GUN 2.

19	3.204	3.204	3.303	55	3.206	3.205	3.303
21	3.204	3.203	3.303	57	3.206	3.206	3.303
23	3.204	3.204	3.303	59	3.206	3.206	3.303
25	3.204	3.204	3.303	61	3.206	3.206	3.303
27	3.204	3.204	3.303	63	3.206	3.206	3.302
29	3.205	3.204	3.303	65	3.206	3.206	3.302
31	3.205	3.204	3.303	67	3.206	3.206	3.302
33	3.205	3.204	3.303	69	3.206	3.206	3.302
35	3.205	3.204	3.303	71	3.206	3.206	3.302
37	3.205	3.204	3.303	73	3.206	3.206	3.302
39	3.205	3.205	3.303	75	3.206	3.206	3.302
41	3.205	3.204	3.302	77	3.206	3.206	3.302
43	3.205	3.204	3.302	79	3.206	3.206	3.302
45	3.205	3.204	3.302	81	3.206	3.206	3.302
47	3.205	3.205	3.302	83	3.206	3.206	3.303
49	3.205	3.205	3.302	85	3.205	3.205	3.302
51	3.206	3.205	3.303	87	3.206	3.207	3.302
53	3.206	3.205	3.303	89	3.205	3.205	3.302

GUN 3.

19	3.200	3.200	3.300	55	3.201	3.201	3.300
21	3.200	3.200	3.300	57	3.201	3.201	3.300
23	3.200	3.200	3.300	59	3.201	3.201	3.301
25	3.200	3.200	3.300	61	3.201	3.201	3.300
27	3.200	3.200	3.300	63	3.201	3.201	3.300
29	3.200	3.200	3.300	65	3.201	3.201	3.300
31	3.200	3.200	3.301	67	3.201	3.201	3.301
33	3.200	3.200	3.301	69	3.201	3.201	3.301
35	3.200	3.200	3.301	71	3.201	3.201	3.301
37	3.200	3.200	3.300	73	3.201	3.201	3.301
39	3.200	3.200	3.301	75	3.202	3.201	3.301
41	3.201	3.200	3.301	77	3.202	3.201	3.301
43	3.201	3.200	3.301	79	3.202	3.201	3.300
45	3.201	3.200	3.301	81	3.202	3.201	3.301
47	3.201	3.201	3.301	83	3.202	3.201	3.301
49	3.201	3.201	3.301	85	3.202	3.201	3.301
51	3.201	3.201	3.301	87	3.202	3.201	3.301
53	3.201	3.201	3.301	89	3.202	3.201	3.301

REMARKS.

The fabrication of a new gun quite complicated in its structure and requiring fine workmanship is at first attended with some difficulties, the principal of which is that of procuring workmen sufficiently skilled in close and fine work to be able to turn and bore the surfaces accurately and make the parts of the breech mechanism fit perfectly together and to be interchangeable between different guns. This latter requirement necessitated the making of many templates. Numbers of tools, fixtures, and appliances were also made for use with these few guns, which would of course be available for many more. Indeed, five guns is just about enough to give the proper instruction to a gang of men and to get a proper supply of such accessories as to enable us to go on in the construction with celerity and economy.

The number of hours' work given above as necessary to complete the different parts is an average for these guns now reported on, but it should not be inferred that that number of hours would not be considerably reduced in the next five guns. Twenty-five guns could be made at a less cost per gun than five.

The foreman and another workman were the only men who had had any experience with this class of guns and almost the only ones who had ever worked on guns. Several men were tried and found wanting, and others were instructed; but, as might be expected, mistakes were made and mishaps occurred. These were as follows:

In shrinking together the first gun, because of the inexperience of the assistants a close joint was not made between the sleeve and trunnion-hoop. This was remedied by calking.

Again, in screwing in the first base-ring the inside threads were injured. It had to be bored out and another one used.

In heating the trunnion-hoop for the fourth gun it was found that even a red heat failed to expand it sufficiently to get it over the lip of the locking-joint on the jacket. It was therefore withdrawn and another trunnion-hoop used. If it is determined to use the hoop which failed to expand, the taper of the lip will be slightly changed.

It will be observed from Table 4 that guns 1 and 2 were slightly overbored. It is of course a difficult matter to bore to exact dimensions, and it is probably never accomplished; but in order to approximate to within one-thousandth of an inch, one or more inches of extra length of tube forging is requisite, which surplus length we did not have.

The method of heating by wood fire offers some advantages for these small guns, but upon the whole is not as convenient or as controllable as a heating furnace would be. If a sufficient number of guns to authorize the expense were to be made, it would be best to build such a furnace for future use.

It is thought that the following defects may be found in service in the use of this gun:

(1) It has no automatic method of preventing firing before the breech-block is closed and locked in its place. This defect cannot, I believe, without fundamental changes, be remedied. The only partial remedy is to take extra precautions when firing to see that the lever is closed down, which alone indicates that the gun is in condition to fire. Too much care cannot be exercised on this point.

(2) The lever-handle is now too loose on its hinge. Any rapid movement of the battery, especially over rough ground, will cause this lever to flop up and down, to the danger of loosening the block and injuring the lever itself. A friction spring or some other simple device could easily be put in to remedy this defect.

(3) The bronze handle, not being in the center of the block, draws to one side, and therefore requires a little more care and effort in withdrawing and inserting the block to prevent sticking or binding. It requires, in fact, both hands to manipulate it with certainty. This defect, if it can be called one, cannot probably be remedied.

The inspection reports of the three completed guns are appended.

Inspection report, &c.

GUN 1.*

Subject of measurement.	Dimensions— Prescribed.	Dimensions— Actual.
	Inches.	*Inches.*
Length of gun (total)	90.7	90.7
Length of bore	83.2	83.2
Maximum diameter	9.56	9.56
Length of tube	83.2	[illegible]
Exterior diameter of tube for 18 inches from rear	6.009	[illegible]
Exterior diameter of tube from 18 inches from rear to 42.50 inches	5.608	[illegible]
Exterior diameter at the muzzle	5.10	5.10
Interior diameter of powder-chamber (maximum)	3.8	3.790
Length of powder-chamber	10.0	10.0
Length of jacket	27.15	27.15
Maximum exterior diameter of jacket	9.56	9.56
Minimum exterior diameter of jacket	8.40	8.40
Inside diameter of jacket from rear to 23.5 inches	6.00	[illegible]
Inside diameter of jacket for 3.65 inches from front end	5.60	[illegible]
Length of locking-shoulder	1.25	1.25
Exterior diameter at extreme of locking-shoulder	6.602	[illegible]
Exterior diameter, at face of jacket, of locking-shoulder	6.559	[illegible]
Corresponding diameters of recess in trunnion-band	6.530 6.5928	[illegible] [illegible]
Length of trunnion-band	8.80	[illegible]
Exterior diameters of trunnion-band (tapering)	8.40 7.60	8.40 [illegible]
Interior diameter of trunnion-band (except locking-recess)	5.60	[illegible]
Diameter of trunnions	3.80	[illegible]
Length of trunnions	2.85	2.85
Distance between rim-bases	8.50	[illegible]
Diameter of rim-bases	4.80	[illegible]
Length of base-ring	4.00	[illegible]
Diameter of base-ring outside of threads	6.35	6.35
Inside diameter of base-ring (breech-plug threads)	4.03	4.03
Outside, threaded a length of	3.80	[illegible]
Inside, threaded a length of	4.00	[illegible]
Length of sleeve	12.30	[illegible]
Exterior diameters of sleeve (tapering)	6.80 6.60	[illegible] [illegible]
Inside diameter of sleeve	5.60	[illegible]
Length of key ring	3.00	[illegible]
Exterior diameters of key ring (tapering)	6.50 6.30	[illegible] [illegible]
Inside diameter of screw-threads of key-ring	5.22	[illegible]
Pitch of screw-threads of key-ring	0.28	[illegible]
Pitch of screw-threads of base-ring (outside)	0.25	0.25
Pitch of screw-threads of breech-plug	0.40	[illegible]
Length of breech-plug (total)	6.45	[illegible]
Diameter of breech-plugs (outside threads)	4.47	4.47
Distance from rear end of jacket to center of trunnions	30.30	[illegible]
Length of rifling	71.525	[illegible]
Number of grooves	24.	24.
Number of lands	24.	24.
Width of lands	0.1188	[illegible]
Width of grooves	0.30	[illegible]
Depth of grooves	0.05	[illegible]

* Twist uniform, one turn in 30 calibers, 6° angle; weight of gun, 801½ pounds; preponderance, 5¾ pounds.

Inspection report, &c.—Continued.

GUN 2.†

Subject of measurement.	Dimensions—	
	Prescribed.	Actual.
	Inches.	*Inches.*
Length of gun (total	90.7	90.7
Length of bore	83.2	83.2
Maximum diameter	9.56	9.56
Length of tube	85.2	85.2
Exterior diameter of tube for eighteen inches from rear	6.009	6.009
Exterior diameter of tube from 18 inches from rear to 42.50 inches	5.608	5.608
Exterior diameter at muzzle	5.10	5.10
Interior diameter of powder-chamber (maximum)	3.8	3.798
Length of powder-chamber	10.0	10.00
Length of jacket	27.15	27.15
Maximum exterior diameter of jacket	9.56	9.56
Minimum exterior diameter of jacket	8.40	8.40
Inside diameter of jacket from rear to 23.5 inches	6.00	5.999
Inside diameter of jacket for 3.65 inches from front end	5.60	5.599
Length of locking-shoulder	1.25	1.25
Exterior diameter at extreme of locking-shoulder	6.602	6.004
Exterior diameter at face of jacket of locking-shoulder	6.599	6.560
Corresponding diameters of recess in trunnion-band	6.550 6.5928	6.549 6.595
Length of trunnion-band	8.80	8.80
Exterior diameters of trunnion-band (tapering)	8.40 7.60	8.40 7.60
Interior diameter of trunnion-band (except locking-recess)	5.60	5.599
Diameter of trunnions	3.80	3.80
Length of trunnions	2.85	2.85
Distance between rim-bases	9.50	9.50
Diameter of rim-bases	4.80	4.799
Length of base-ring	4.00	4.00
Diameter of base-ring outside of threads	6.35	6.35
Inside diameter of base-ring (breech-plug threads)	4.03	4.03
Outside, threaded a length of	3.80	3.80
Inside, threaded a length of	4.00	4.00
Length of sleeve	13.30	13.30
Exterior diameters of sleeve (tapering)	6.80 6.60	6.80 6.60
Inside diameter of sleeve	5.60	5.599
Length of key-ring	3.00	3.00
Exterior diameters of key-ring (tapering)	6.50 6.30	6.50 6.30
Inside diameter of screw-threads of key-ring	5.32	5.32
Pitch of screw-threads of key-ring	0.26	0.26
Pitch of screw-threads of base-ring (outside)	0.25	0.25
Pitch of screw-threads of breech-plug	0.40	0.40
Length of breech-plug (total)	6.45	6.45
Diameter of breech-plug (outside threads)	4.47	4.47
Distance from rear end of jacket to center of trunnions	30.30	30.30
Length of rifling	71.525	71.530
Number of grooves	24.	24.
Number of lands	24.	24.
Width of lands	0.1188	0.1188
Width of grooves	0.30	0.30
Depth of grooves	0.05	0.05

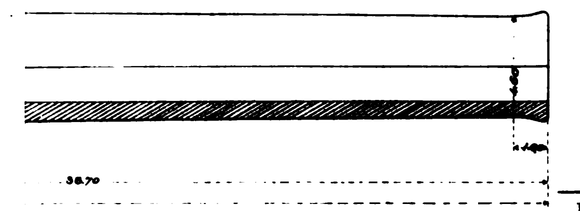
† Twist uniform, one turn in 30 calibers, 6° angle; weight of gun, 804½ pounds; preponderance, 57 pounds.

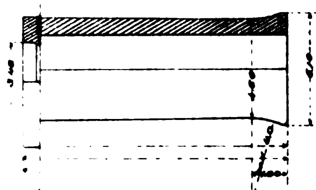
Inspection report, &c.—Continued.

GUN 3.*

Subject of measurement.	Dimensions—	
	Prescribed.	Actual.
	Inches.	*Inches*
Length of gun (total)	90.7	90.7
Length of bore	83.2	83.2
Maximum diameter	9.56	9.56
Length of tube	85.2	85.2
Exterior diameter of tube for 18 inches from rear	6.008	6.007
Exterior diameter of tube from 18 inches from rear to 42.50 inches	5.6075	5.606
Exterior diameter at muzzle	5.10	5.10
Interior diameter of powder-chamber (maximum)	3.8	3.78
Length of powder-chamber	10.0	10.00
Length of jacket	27.15	27.15
Maximum exterior diameter of jacket	9.56	9.56
Minimum exterior diameter of jacket	8.40	8.40
Inside diameter of jacket from rear to 23.5 inches	6.00	5.990
Inside diameter of jacket for 3.65 inches from front end	5.60	5.590
Length of locking-shoulder	1.25	1.25
Exterior diameter at extreme of locking-shoulder	6.602	6.602
Exterior diameter, at face of jacket, of locking-shoulder	6.559	6.557
Corresponding diameters of recess in trunnion-band	6.550 6.5928	6.550 6.5900
Length of trunnion-band	8.80	8.80
Exterior of diameters of trunnion-band (tapering)	8.40 7.60	8.40 7.60
Interior diameter of trunnion-band (except locking-recess)	5.60	5.590
Diameter of trunnions	3.80	3.80
Length of trunnions	2.85	2.85
Distance between rim-bases	9.50	9.50
Diameter of rim-bases	4.80	4.80
Length of base-ring	4.00	4.00
Diameter of base-ring outside of threads	6.35	6.35
Inside diameter of base-ring (breech-plug threads)	4.03	4.03
Outside, threaded a length of	3.80	3.80
Inside, threaded a length of	4.00	4.00
Length of sleeve	13.30	13.30
Exterior diameters of sleeve (tapering)	6.80 6.60	6.80 6.60
Inside diameter of sleeve	5.60	5.5965
Length of key-ring	3.00	3.00
Exterior diameters of key-ring (tapering)	6.50 6.30	6.50 6.30
Inside diameter of screw-threads of key-ring	5.32	5.32
Pitch of screw-threads of key-ring	0.26	0.26
Pitch of screw-threads of base-ring (outside)	0.25	0.25
Pitch of screw-threads of breech-plug	0.40	0.40
Length of breech-plug (total)	6.45	6.45
Diameter of breech-plug (outside threads)	4.47	4.47
Distance from rear end of jacket to center of trunnions	30.30	30.30
Length of rifling	71.525	71.530
Number of grooves	24.	24.
Number of lands	24.	24.
Width of lands	0.1188	0.1182
Width of grooves	0.30	0.30
Depth of grooves	0.05	0.05

* Twist, uniform, one turn in 30 calibers, 6° angle; weight of gun, 604¾ pounds; preponderance, 57½ pounds.

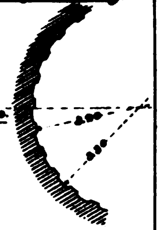


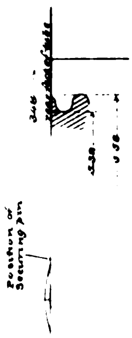


Rifling.

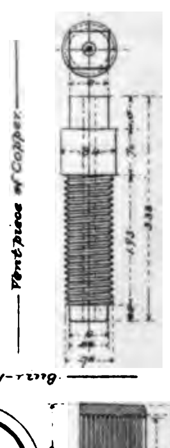
No. of Lands	24
" " Grooves	24
Width " "	0.30
" " Lands	0.1166
Depth " Grooves	0.050
Twist uniform one turn in 30 calibers.	

Section through Rifling.

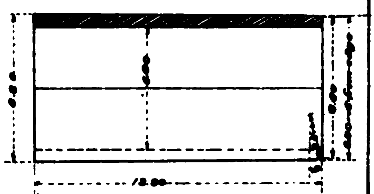




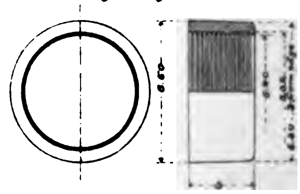
Vent piece of Copper.



Sleeve

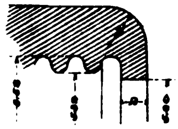


Key-ring.



Base-ring.

Front of Key-ring enlarged.



H E

APPENDIX 31.

REPORT ON PACKING OUTFIT FOR THE HOTCHKISS MOUNTAIN GUN

BY LIEUT. COL. D. W. FLAGLER, ORDNANCE DEPARTMENT.

(17 plates.)

ROCK ISLAND ARSENAL, ROCK ISLAND, ILL.,
December 31, 1885.

SIR: In compliance with your instructions, I have prepared and have the honor to transmit herewith a report on the subject of packing the Hotchkiss mountain gun, carriage, and ammunition; and traction of the gun and carriage; with drawings, and description of pack-saddles and packing outfit, and draught harness, and traction outfit, which I have prepared and recommend for the service. The saddles and packing outfit which I have prepared have been so many times altered and improved, while testing, using, and perfecting them, that they are now only fit to serve as models in making others, and to show more clearly, than drawings can, all the devices. As suggested in the report, and for reasons given there, I think if these plans are approved, one or more complete packing outfits should be made and subjected to trial in actual service before the final adoption of exact models.

I regret the long time which has been required for the preparation of this report and for the preparation and trial of the packing outfit, but it has involved much tedious labor on a subject with which I have heretofore had no experience, and needed an amount of leisure which it was hard to obtain from other work.

Very respectfully, your obedient servant,

D. W. FLAGLER,
Lieutenant-Colonel of Ordnance, Commanding.

The CHIEF OF ORDNANCE U. S. A.
Washington, D. C.

HOTCHKISS MOUNTAIN GUN PACK.

LIST OF DRAWINGS.

Gun and wheels pack.

Plate I.—Pack-saddle for gun and wheels (side view).
Plate II.—Pack-saddle with gun (only) in position (side view).
Plate III.—Pack-saddle with gun and wheels packed (side view).
Plate IV.—Pack-saddle with gun and wheels packed (end view).
(Details of cargo cincha, and wheel pads for gun and wheels pack-saddle are shown in detail drawing, Plate XIII.)

Gun-carriage, and harness pole, pole-yoke, and splinter-bar pack.

Plate V.—Pack-saddle for carriage, harness, &c. (side view).
Plate VI.—Pack-saddle for carriage, harness, &c., with only harness, pole, pole-yoke, and splinter packed (side view).
Plate VII.—Pack-saddle with carriage, harness, pole, pole-yoke, and splinter bar packed (left side view).
Plate VIII.—Pack-saddle with carriage, harness, pole, pole-yoke, and splinter bar packed (right side view).
(Details of cargo cincha for gun-carriage, harness, &c., packs are shown on detail drawing, Plate XIV.)
Plate IX.—Mules hitched to carriage for draught (off mule omitted).

Ammunition pack.

Plate X.—Pack-saddle for ammunition (side view).
Plate XI.—Pack-saddle with ammunition packed—six boxes with 12 rounds in each box (side view).
Plate XIII.—Detail drawing.
Fig. 1. Cargo cincha, showing wheel pads.
Fig. 2. Belly cincha, with wheel straps.
Fig. 3. Gun pad, to protect gun from wheels.
Plate XIV.—Detail drawing.
Fig. 1. Splinter bar.
Fig. 2. Pole.
Fig. 3. Carriage, showing splinter-bar hooks.
Plate XV.—Detail drawings.
Figs. 1 and 2. Plan and side view of cincha for packing carriage.
Figs. 3, 4, and 5.—Front view, section, and side view of wooden cincha block.
Plate XVI.—Ammunition-box.
Fig. 1. Bottom view.
Fig. 2. Side view
Fig. 3. Horizontal section.
Fig. 4. Vertical and longitudinal section.
Fig. 5. End view with cover removed.
Plate XVII.—Showing model of packing 2 ammunition boxes on gun-carriage pack.

ROCK ISLAND ARSENAL,
December 26, 1885.

THE HOTCHKISS MOUNTAIN GUN PACK.

APARÈJOS.

Aparèjo and *albarda* are the two Spanish words for pack-saddle. The latter is, perhaps, more generally used for pack-saddle, as the former is also the general word for harness, tackle, gear, apparatus, &c. I think in our service we have come to use the word aparèjo to distinguish the packing *pads*, which Spanish nations use for miscellaneous packing on animals, from the permanent *pack-saddles* which we use. The aparèjo used for miscellaneous packing by the Mexican people consists of a pad, generally about 30 inches long, lengthwise of the animal's body, and about 4 feet wide, measured from bottom to bottom over the animal's back; or of two pads fastened together along the animal's backbone, which, taken together, will give about the above dimensions. These pads are stuffed sacks, the sacks being made of leather or canvas, or old gunny sacks, &c. The expert packer first collects and makes a study of the articles or load to be packed. He then stuffs the pads with hay, straw, tow, grass, brush, and sticks, or whatever is available, having in view the requirements of the load he is to pack. For the best packing he is provided with many flat elastic tough wooden sticks. The pad-

ding and these sticks are arranged to relieve the animal's back and sides from hard pressures on small areas by forming springs, which spread such pressures over large areas. This stuffing the pads for particular loads is an important part of the packing, and requires natural aptitude and long experience to give excellence. It is carried on, and altered and perfected, through study and feeling the pressures, not only while the load is being packed, but throughout the march. During the first days of the march the packer will frequently change and improve this padding, for the better protection of the animals, until it is so perfect as to remove the danger of sore backs.

The aparèjo is fastened to the animal with the aparèjo (or saddle) cincha. The padding is arranged to spread this pressure also, and give the pad a better *grip* on the animal's body.

Packing.—Articles are packed on and fastened to the aparèjo with a cargo cincha over all and around the animal's body, and by lashing thongs and ropes, generally attached to the cargo cincha and drawn over the articles and underneath the corners of the pads and over the back of the animal, in various ways, depending on the expertness of the packers.

After the pads are stuffed and secured to the animal, perfection in packing consists in so arranging the load that—

(1) It shall ride securely.

(2) It shall not hurt the animal.

(3) It shall occupy the least possible space, and have its center of gravity as near as may be at the proper point; that is, so that changes of the animal's position will change the position of the center of gravity of the load with reference to the animal as little as possible. Perfection in this kind of packing depends on the natural aptitude of the packer, and requires a life-time of learning and experience. It is the most perfect method of packing if expert packers are at hand. The mere description of the method, however, shows clearly that it is not available for and would not meet the wants of our service in packing guns, carriages, and ammunition in active service. Expert packers for these articles would not be at hand at the times when and places where such packing would be required suddenly. Certainty of being able to pack a gun, &c., in some way is of the *first* importance. Then the packing should be as perfect as is practicable.

The next best method of packing, and apparently the only one available when expert packers are not at hand, is to provide a *pack-saddle*, or *permanent* aparéjo, which shall fulfill the conditions of the aparéjo as nearly as possible, and on which soldiers and men of ordinary intelligence and little or no experience can pack a load, probably *not* in the very best manner, but with certainty.

In consequence of the difficulty or impossibility of procuring expert packers when required suddenly for Army service, the Quartermaster Department has adopted and is now using a permanent pack-saddle, devised by Mr. Thomas Moore, and known, I believe, as the Moore pack-saddle.

The reasons for adopting a permanent pack-saddle, instead of an aparéjo, for the mountain-gun pack, are more apparent and more imperative. The articles to be packed being always precisely the same, it should be possible to devise a better special pack-saddle for the special case. A commanding officer of a post is more likely to be called upon hastily to pack a gun, &c., for an expedition than the Quartermaster Department is to pack supplies, and he is less likely to have expert packers at hand.

tufted and laced to saddle skirts with rawhide thongs and screwed securely to side bars along top edge of pad through leather facings.

Saddle cinchas, made of No. 1 cotton duck, 10 inches wide, with a latigo iron on each end, with chapes, and sewed to cincha; one latigo strap sewed into latigo iron; one circular piece of leather, 3½ inches in diameter, with leather thong (into which the latigo strap is fastened after lashing on saddle) sewed on cincha, 13 inches from end on same end as latigo strap.

Crupper is composed of 2 leather side pieces and 1 dock; side pieces are lined with light leather and stitched together; two side pieces joined, dock sewed around center and stuffed, and ends sewed on side pieces; side pieces re-enforced on each end by a 2-inch strip of leather, with holes punched for lacing to saddle with a rawhide thong.

Cargo cinchas are made of 2 thicknesses of No. 1 cotton duck, 10 inches wide, with latigo irons and straps on each end, with holes punched for belly cincha buckle-tongue.

Cargo cincha for carriage is faced in center with leather, which has a slot, 10 inches long, for passing over elevating screw of carriage, and is screwed on a block which fits between the flanges of the trail of the carriage.

Cargo cincha for gun and wheels is faced with leather, which is left long enough to make chapes for latigo irons; 2 slots in center to pass over trunnions of gun; 2 pads sewed on each side, 3½ inches wide, to support the wheels.

Cargo cincha for ammunition is made 16 inches longer than the others mentioned, with latigo irons and straps, but no facings.

Belly cinchas are made of 3 thicknesses of No. 1 cotton duck, 7½ inches wide, with a buckle, 5½ inches wide, with brass roller, and chapes sewed on each end.

Belly cincha for gun and wheel has 2 chapes, with buckles and billets sewed on each chape for securing the wheels.

A semicircular pad, stuffed with tow, 3 inches wide and 3½ inches high, with buckles and billets, is strapped on rear of gun to protect it from the wheels.

Dimensions of leather parts of Hotchkiss mountain-gun pack outfit.

	No.	Width.	Length.	
			Cut.	Finished.
Saddle:		*Inches.*	*Inches.*	*Inches.*
Skirts	2	25.75	17.25	[illegible]
Under covers	2	25.	10.5	[illegible]
Carriage saddle:				
Harness straps	2	0.875	42.	[illegible]
Pole straps	2	1.	41.	[illegible]
Pads:				
Facings, front	2	8.	41.5	41.5
Facings, rear	2	4.	46.	[illegible]
Facings, top	2	2.	25.25	[illegible]
Sockets	4	5.5	5.75	[illegible]
Crupper:				
Side pieces	2	11.5	22.	[illegible]
Side-piece linings	2	12.5	22.	21.5
Dock	1	7.5	10.75	[illegible]
Re-enforce	2	2.	11.5	11.5
Saddle cincha:				
Latigo strap	1	1.25	90.	[illegible]
Chapes	2	10.	8.75	[illegible]
Cargo cincha:				
Latigo straps	2	2.	90.	[illegible]
Chapes	2	10.	8.75	[illegible]
Cargo cincha carriage, facing	1	10.	12.	[illegible]
Cargo cincha gun:				
Pads	4	9.25	10.5	[illegible]
Facings and chapes	1	10.	58.5	[illegible]
Belly cincha, chapes	2	5.5	8.5	4.75
Belly cincha gun:				
Billets	4	1.5	36.	[illegible]
Chapes	4	1.5	10.	[illegible]
Straps:				
Wheel	1	1.	20.5	[illegible]
Hub, billet	1	1.25	21.	22.5
Hub, body	1	1.25	21.	[illegible]

Dimensions of duck parts of Hotchkiss mountain-gun pack outfit.

	No.	Width.	Length.	
			Cut.	Finished.
		Inches.	*Inches.*	*Inches.*
Saddle pads	2	25.	46.	23.
Saddle cincha	1	22.	65.	64.
Cargo cinchas:				
Carriage	1	22.	52.	51.
Wheel	1	22.	52.	51.
Ammunition	1	22.	68.	67.
Belly cincha	1	22.5	20.	19.

DRAUGHT HARNESS FOR TWO MULES.

Bridle (black bridle leather) is composed of 1 headstall, 1 pair of reins, 1 bit.

Headstall: 1 crown-piece, split 7 inches on each end, forming cheek and throat-lash billets; 1 buckle and chape in center; 2 cheeks, made by folding and sewing each strap together 9¼ inches, each containing therein 2 buckles, 5 loops, and 1 winker (winker, made of 2 thicknesses of leather and sewed together around the edges); the remainder of the strap forms a billet for attaching the bit.

One winker-strap, split 7 inches, and sewed into the winker, the other end cut to a ⅝-inch billet, for buckling to the crown-piece.

One brow-band, the ends doubled and sewed from 2 loops, through which pass cheek and throat-lash billets.

One throat-lash, ends doubled and sewed, each containing 1 buckle and loop.

Two reins, sewed together at one end; the other ends have buckles and billets sewed on for attaching to bit.

One bit (malleable iron), with loose rings 2⅝ inches diameter, and jointed mouth-piece.

Breast-collar: 1 body, 1 neck-strap, 4 tugs.

Body of single leather, with under edges reduced so as not to chafe the animal; 1 chape, with 1½-inch iron ring sewed in the center; 1 lay, with 2 tugs sewed on each side, the tugs placed 17 and 24 inches from end of body; 2 1½-inch buckles and chapes, with 2 loops sewed on body far enough from each end for the projection to make a safe.

One neck-strap, split 15 inches from each end, making ¾-inch billets for buckling into tugs on body.

Four tugs, made of two thicknesses of leather and sewed together, each containing 2 loops, 1 ¾-inch buckle, and 1 ⅞-inch ring.

Back-strap, sewed on center of neck-piece, with holes punched in end, to buckle into tug on breeching.

Traces of single leather, with iron clips riveted on one end for attaching to hooks on splinter-bar.

Breeching: 1 body, 2 breeching-straps, 4 tugs, 2 hip-straps, 1 back-strap tug.

One body, under edges reduced.

Two breeching straps, sewed on body 10 inches, making a lay for tugs, holes punched in ends to buckle to breast-collar.

Four tugs, sewed on body 1 inch, and 8 inches from each end.

Two hip-straps, split 16½ inches from end; the other end is sewed into ring of back-strap tug.

One back-strap tug, made of doubled leather, with 1 buckle, 1 1½-inch ring, and 1 loop, and sewed on safe.

One harness sack, made of No. 8 duck, consisting of 1 body piece 46 inches long and 34½ inches wide, and 2 end pieces each 17½ inches long and 14½ inches wide. These pieces, when sewed together, form a sack 33 inches long and 7 inches deep, with 4 flaps, for covering harness; 2 leather billets are sewed on top flap and 2 buckles and chapes on the body.

Two pole straps, made of single leather, with buckles sewed on end, 1 loop top and bottom of fold.

One brace, made of heavy harness leather, doubled and sewed together part way, leaving an opening large enough to admit neck-yoke; a billet is placed on top of brace, and both are secured in place by a ¾-inch, No. 8, round-head screw, blued.

One trail-strap, made of light leather, with 1 buckle and loop, and is strapped on trail around sponge and staff clasp.

Dimensions of leather parts of harness, Hotchkiss mountain-gun pack outfit.

	No.	Width.	Length. Cut.	Length. Finished.
		Inches.	*Inches.*	*Inches.*
Bridle:				
Crown	1	1.375	23.	[illegible]
Cheeks	2	0.75	27.	[illegible]
Throat-lash	1	0.625	21.	[illegible]
Winker-strap	1	1.25	12.	[illegible]
Brow-band	1	0.75	21.	[illegible]
Reins	2	0.875	60.	[illegible]
Rein billets	2	0.875	12.	[illegible]
Winkers	2	5.	4.5	[illegible]
Winker linings	2	5.	4.5	[illegible]
Breast collar:				
Body	1	1.875	60.	[illegible]
Chapes	2	1.25	10.	[illegible]
Lays	2	1.	10.	[illegible]
Tugs	4	0.75	10.5	[illegible]
Neck-piece	1	1.5	38.	[illegible]
Back-strap	1	1.	40.	[illegible]
Traces	2	1.25	66.	[illegible]
Breeching:				
Body	1	1.625	38.5	[illegible]
Straps	2	1.125	39.	[illegible]
Hip straps	2	1.5	24.	[illegible]
Tugs	4	0.75	13.	[illegible]
Back-strap tug		....	....	....
Straps:				
Trail	1	1.125	16.	[illegible]
Pole	2	1.25	31.	[illegible]
Brace, yoke	1	3.75	12.5	[illegible]
Brace, billet	1	0.625	9.5	[illegible]

Materials required for 20 sets of packing outfit for Hotchkiss mountain-gun and ammunition

860 lbs. harness leather.
400 sq. ft. collar leather, 8½ to 9 oz. per sq. ft.
150 sq. ft. collar leather, 7 to 8 oz. per sq. ft.
14 sides bridle leather, 9 to 10 oz. per sq. ft.
4 sides rawhide.
40 lbs. scrap leather.
175 yds. cotton duck, 25 inches wide, No. 1, unbleached.
34 yds. cotton duck, 36 inches wide, No. 8, unbleached.
40 lbs. manila rope, ⅝ inch diameter.
20 lbs. shoe thread, H. B., No. 10.
1 lb. linen thread, W. B., No. 25, spools.
160 balls black wax.
80 iron barrel roller buckles, 1⅜ inch, japanned.
80 iron barrel roller buckles, 1¼ inch, japanned.
20 iron barrel roller buckles, 1⅛ inch, japanned.
60 iron barrel roller buckles, 1 inch, japanned.
40 iron barrel roller buckles, ⅞ inch, japanned.
40 iron barrel roller buckles, ¾ inch, japanned.
20 iron barrel roller buckles, ⅝ inch, japanned.
40 iron sensible harness buckles, 1 inch, japanned.
80 iron sensible harness buckles, ⅞ inch, japanned.
480 iron sensible harness buckles, ¾ inch, japanned.
160 iron sensible harness buckles, ⅝ inch, japanned.
80 iron sensible trace buckles, 1¼ inch, japanned.
40 jointed bits, loose-ring.
80 iron rings, 1¼ inch, japanned.
320 iron rings, ⅞ inch, japanned.
⅜ pound brass rivets, ½ inch, No. 10 belt.
1 pound brass rivets, ⅝ inch, No. 10 belt.
1 pound brass rivets, ¾ inch, No. 10 belt.
1 pound brass burs, No. 10.
360 iron screws, 1 inch, No. 12.
1040 iron screws, 1½ inch, No. 12.

60 iron screws, ¾ inch, No. 8; round-head, blued.
720 brass screws, 1 inch, No. 6.
60 pairs saddle-bars, wood.
120 cross pieces for pads, wood.
20 blocks for elevating-screw, wood.
60 pairs iron yokes for saddle, japanned.
20 sets irons for carrying carriage, japanned.
20 sets irons for carrying gun, japanned.
20 sets steel springs for carrying ammunition.
60 steel springs, 10¼ inches by 1 inch by ⅛ inch.
60 steel springs, 13½ inches by ⅝ inch by ⅛ inch.
1280 iron rivets, 2½ inches long, ¼ inch thick, flat heads.
120 buckles for 7½-inch cincha, japanned.
120 iron frames for 10-inch cincha, 2-inch latigo strap, japanned.
120 iron frames for 10-inch cincha, 1½-inch latigo strap, japanned.
80 iron clips for traces.
20 iron burs.
60 ammunition boxes.

APPENDIX B.

Directions for packing Hotchkiss mountain-gun outfit and ammunition on the pack-animals' saddles.—Fold saddle blanket in four fold and place it on animal. Place saddle on blanket and cinch tightly with saddle-cincha.

Gun and wheels on first animal.—Place gun in its bearings, breech in front, sight down; put cargo-cincha over gun, trunnions passing through slots, edge of cincha nearest to the slots in front; cinch to belly-cincha. Put gun-pads on breech of gun.

Fasten wheels together with wheel-strap, dish of wheels inside. Place wheels astride of gun, hubs between wheel-pads on cargo-cincha, lower them to proper position and suspend them with the hub-strap, which passes around hubs and over top of gun.

(On most animals the best position for wheels is to have the distance from bottom of hub to bottom of hub, measured over top of saddle, 36 inches.)

Buckle around rim of wheel on each side the two wheel-straps which are attached to belly-chincha chape, two spokes apart on each side. Tighten these straps till wheels are in best position, and bear firmly on the cargo-cincha wheel-pads and on the gun-pad. The wheel-pack is then secure and can be easily adjusted from time to time to aid the animal on the march. If further security is required lash the wheels with the lashing-rope; fasten one end of rope to one hub, pass it around wheels, under corners of saddle-pads and over and under animal and draw tight.

Gun-carriage, draught harness, pole, splinter-bar, pole-yoke, and gunner's pouch on second animal.—Place harness (in its sack) on left side, and pole-yoke under flap of harness-sack and secure them in position with the two straps attached to saddle.

Place pole (butt end in front) and splinter-bar on right side, and secure them in position with the two straps which are attached to the saddle, passing the straps twice around the pole and bar. The front strap passes once in front and once in rear of the pintle-pin.

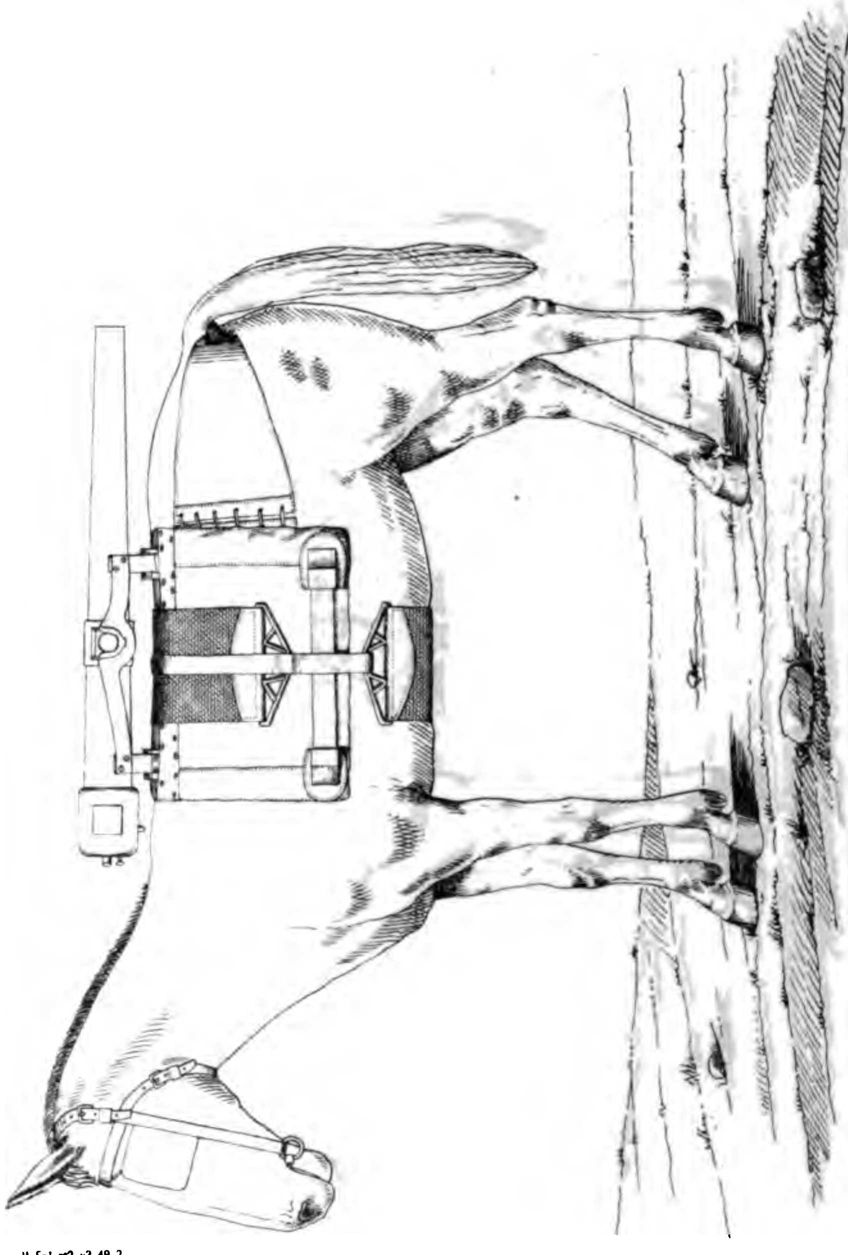
Place carriage in position on top of saddle, bottom down, trail to the rear, so that special shapes of saddle arch-irons will engage in carriage; the front arch-iron enters the slot just in rear of carriage axle. Pass cargo-cincha over carriage, the wooden block down, and in between side flanges of trail, elevating-screw passing through hole in cincha and wooden block. Cinch securely, fasten gunners' pouch strap around gun carriage cheek, and this pack is completed.

(NOTE.—The harness, pole, yoke, and splinter-bar are not necessary to this pack, and the carriage packs equally well without them. If *on* the saddle, they are to be left on it in coming into action; that is, the carriage can be unpacked and repacked without disturbing them.)

When necessary one ammunition-box can be packed (with a lashing-rope) on each side of this saddle after the carriage is on and before the cargo-cincha is put on.)

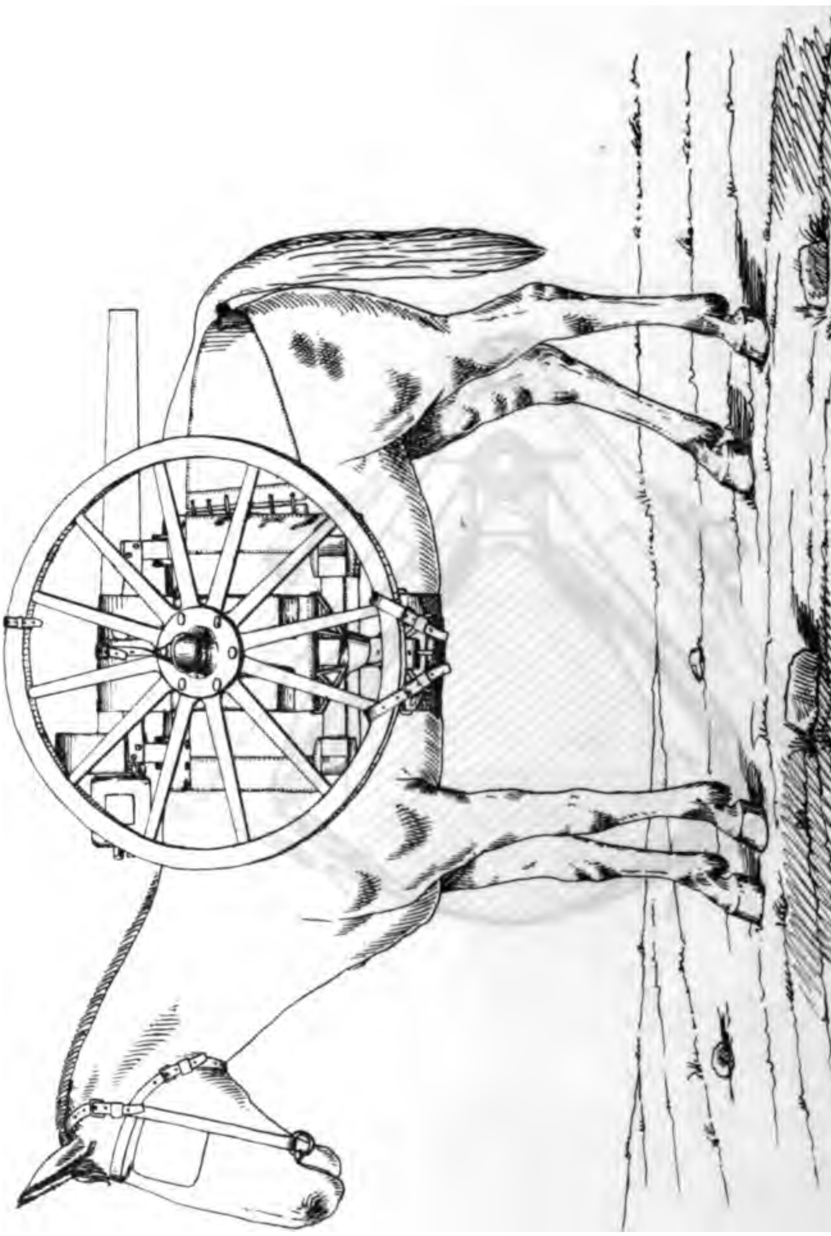
Ammunition, in six ammunition-boxes, 72 rounds, on third animal.—Set on the boxes, notches down, the pins on the saddle entering the notches. Put on the two top boxes first, then pass the cargo-cincha over them, and then add the other boxes from top to bottom on each side, cinch securely with the cargo-cincha, and the pack is completed.

(NOTE.—Six cartridges and 10 primers are packed in each end of each box. Remove the two screws at end of the box, and the box end can be taken out. Screw-driver is packed in gunner's pouch.)



—HOTCHKISS MOUNTAIN GUN PACK.—

PLATE III.

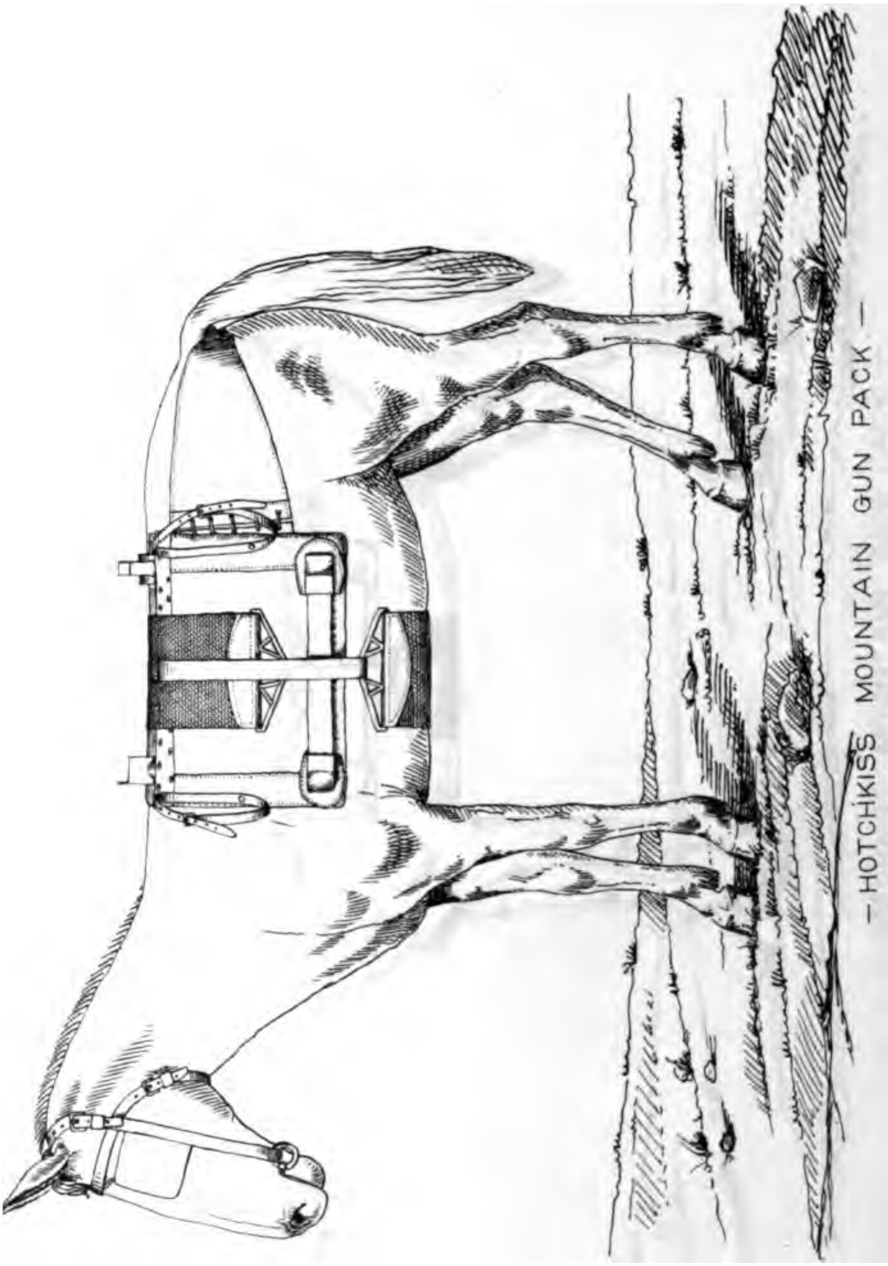


— HOTCHKISS MOUNTAIN GUN PACK. —

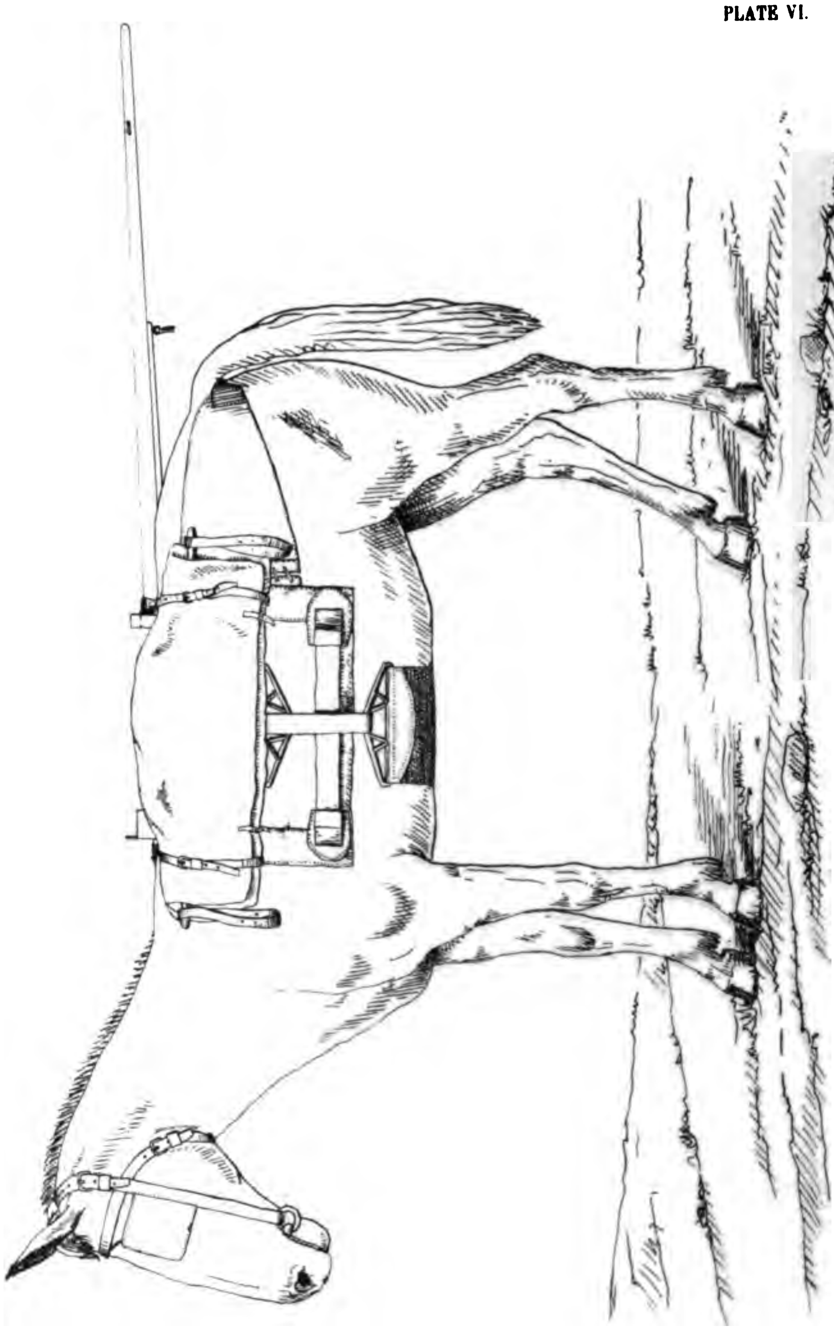
PLATE IV.

— HOTCHKISS MOUNTAIN GUN PACK. —

PLATE V.

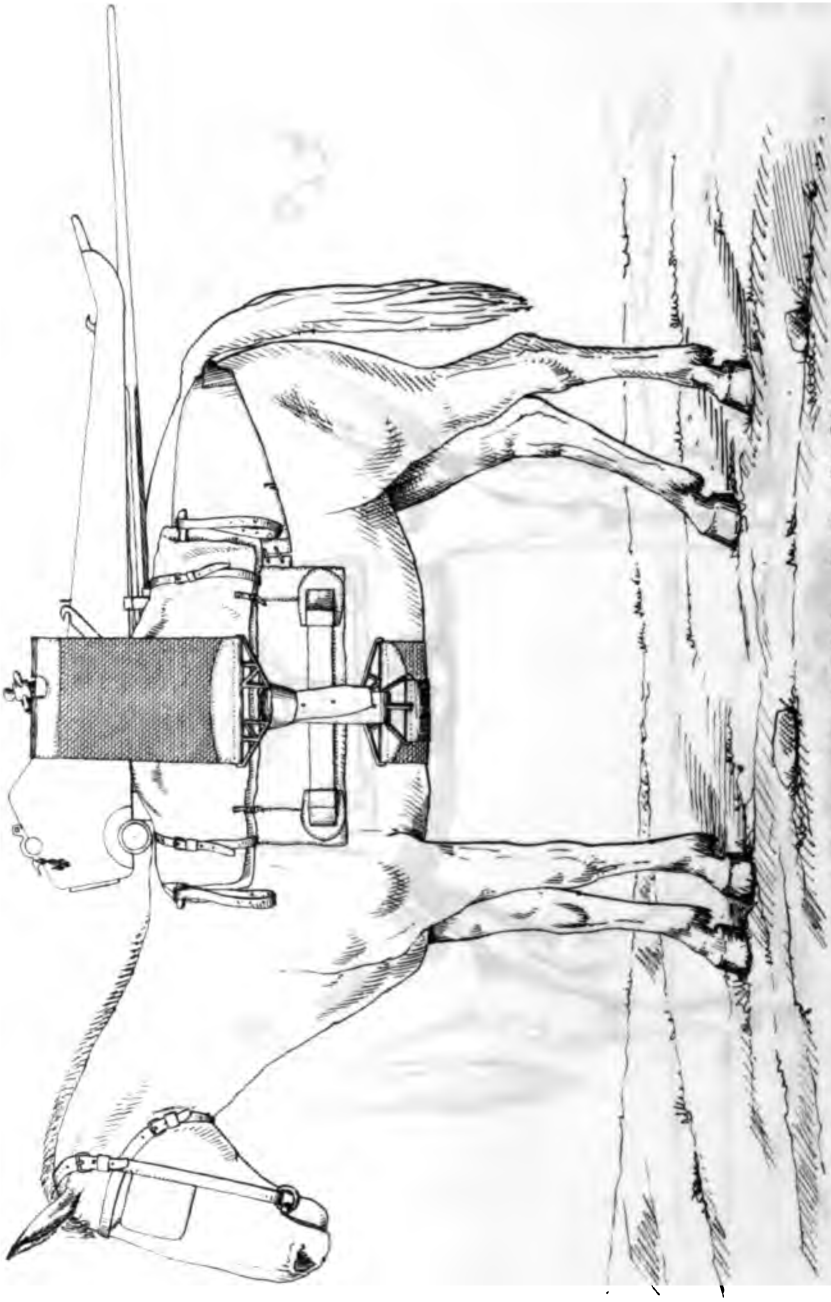


— HOTCHKISS MOUNTAIN GUN PACK —



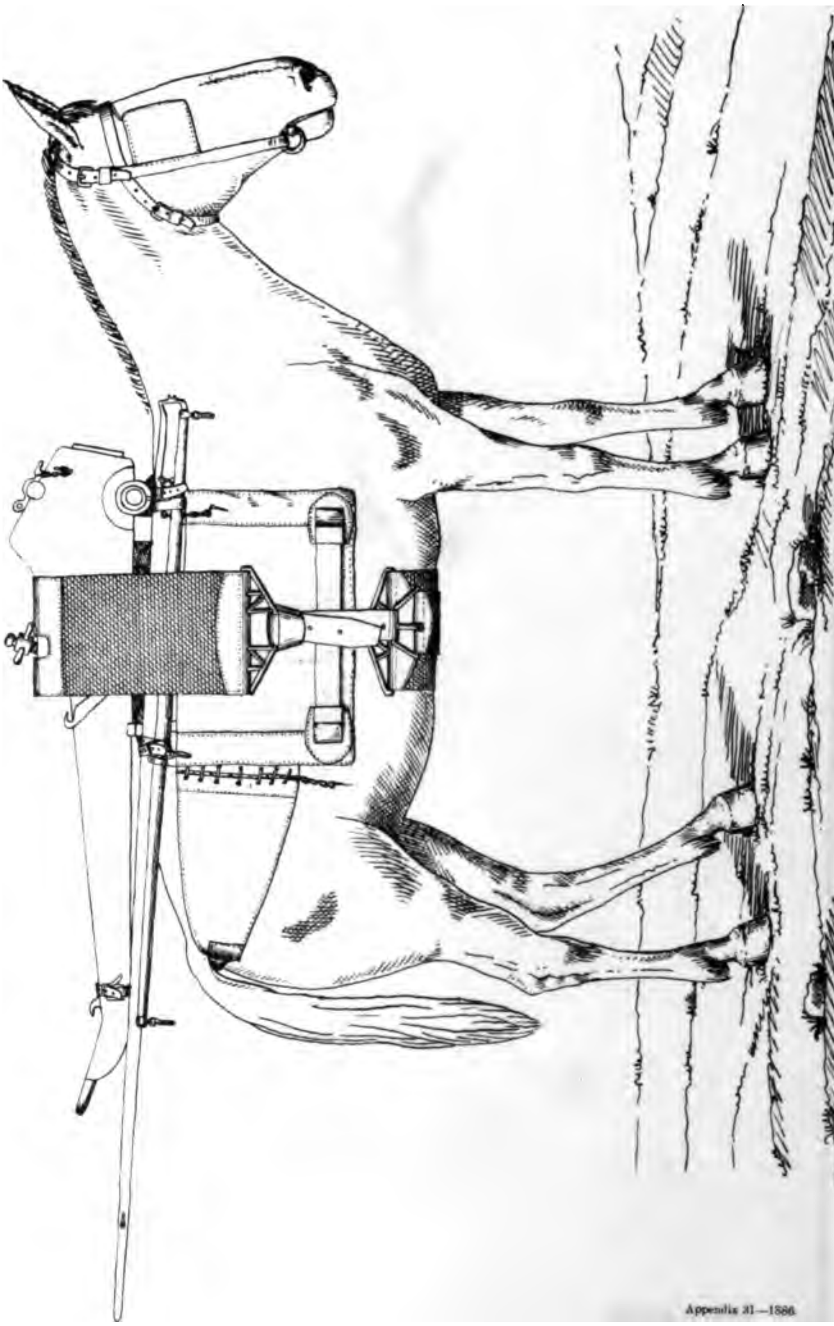
– HOTCHKISS MOUNTAIN GUN PACK. –

PLATE VII.



— HOTCHKISS MOUNTAIN GUN PACK —

PLATE VIII.



— HOTCHKISS MOUNTAIN GUN PACK. —

Appendix 31—1886.

ACK.—

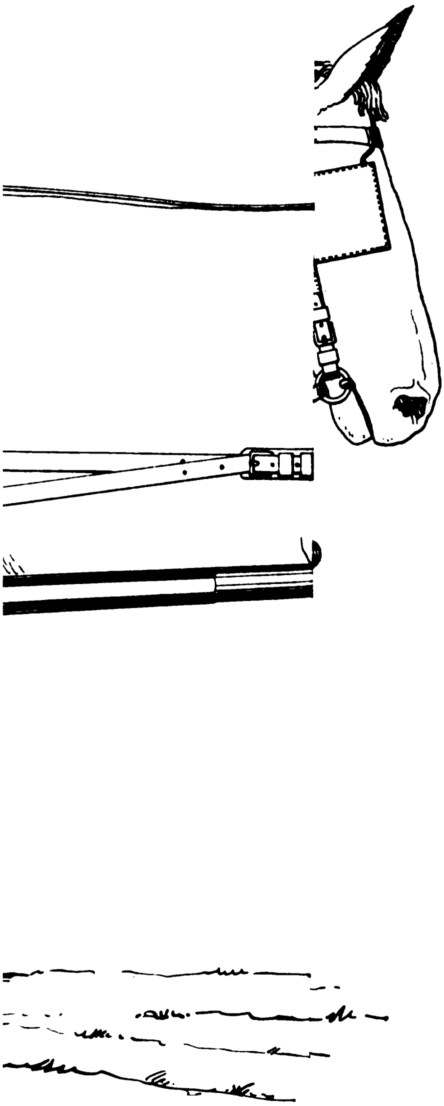
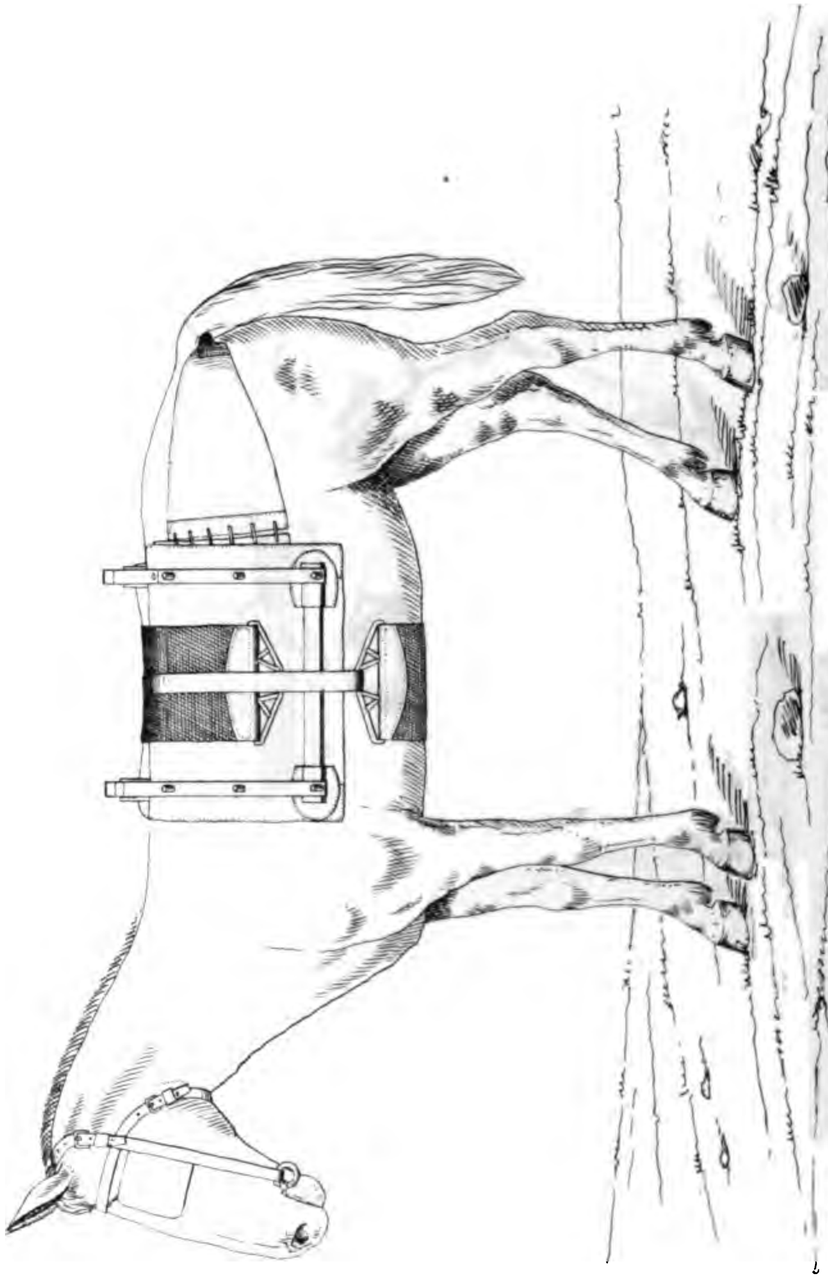


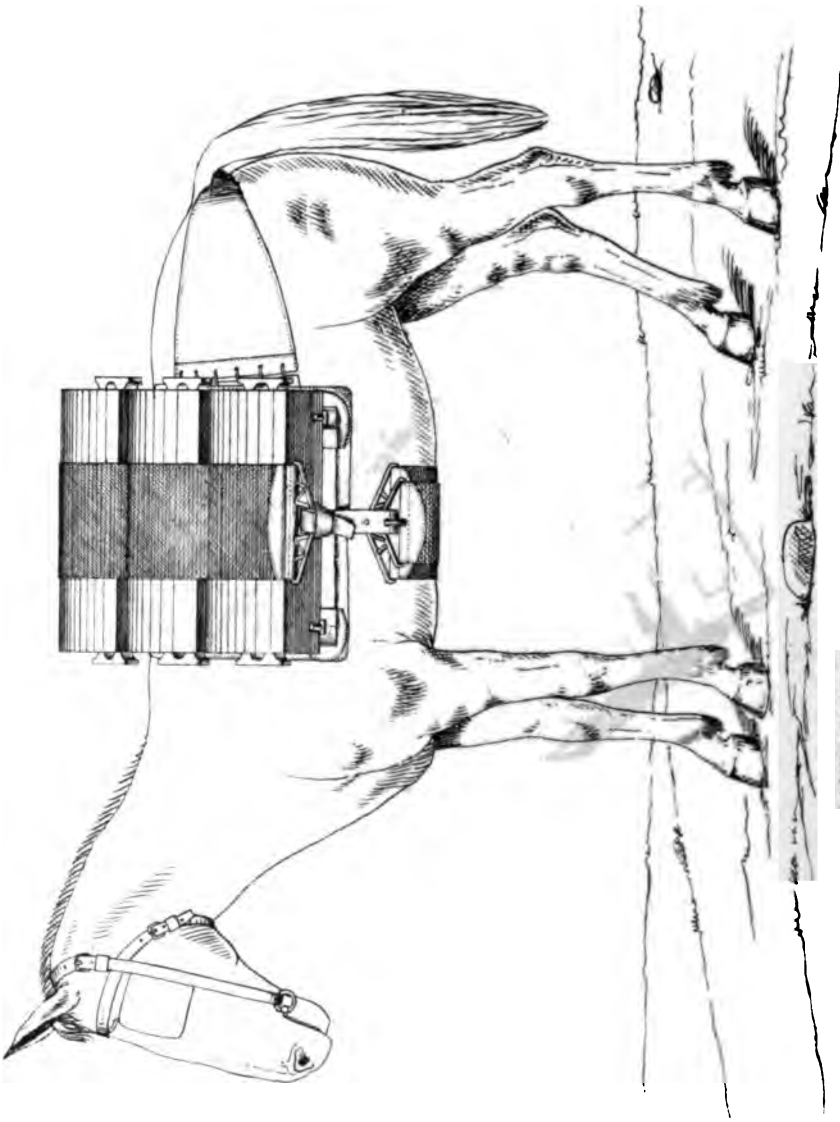
PLATE X.



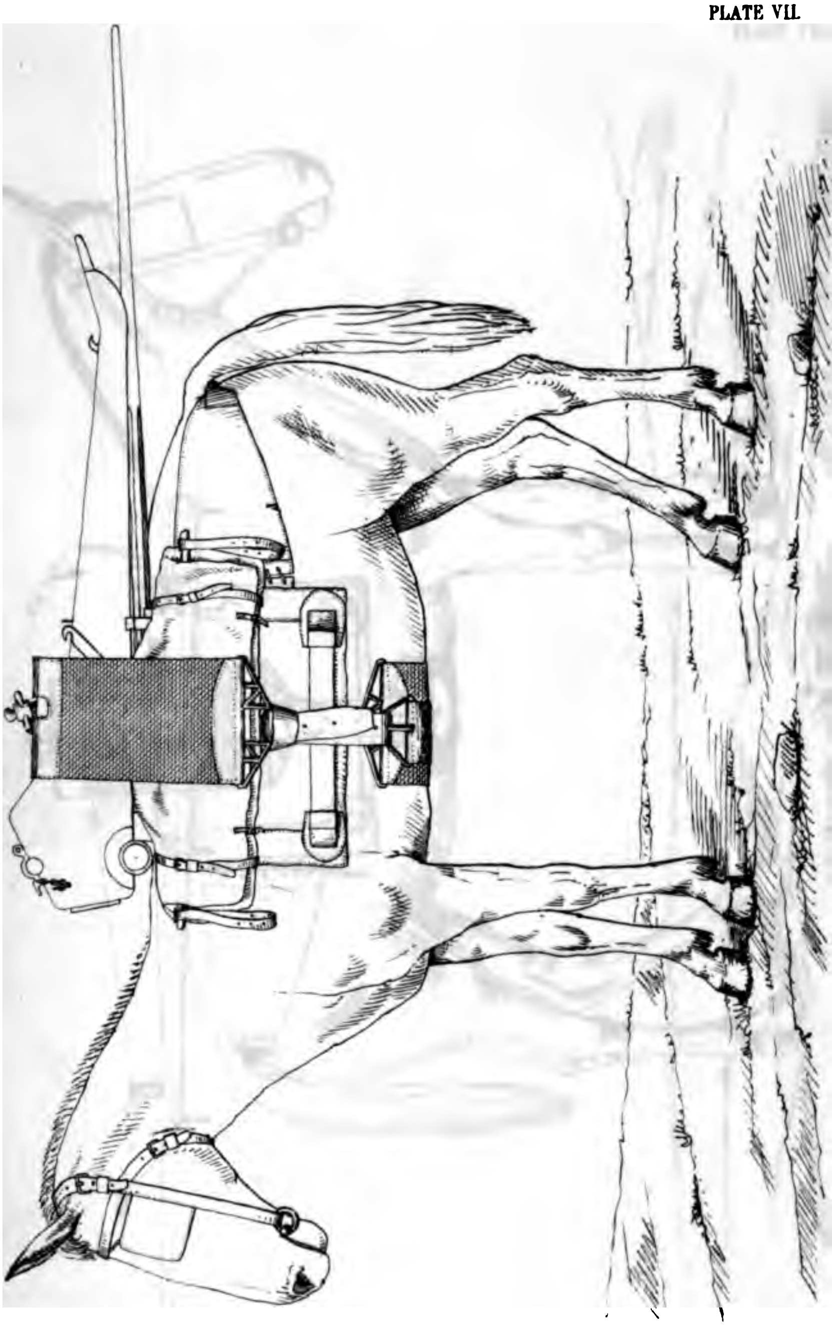
— HOTCHKISS MOUNTAIN GUN PACK. —

Appendix 31—1886.

PLATE XI.

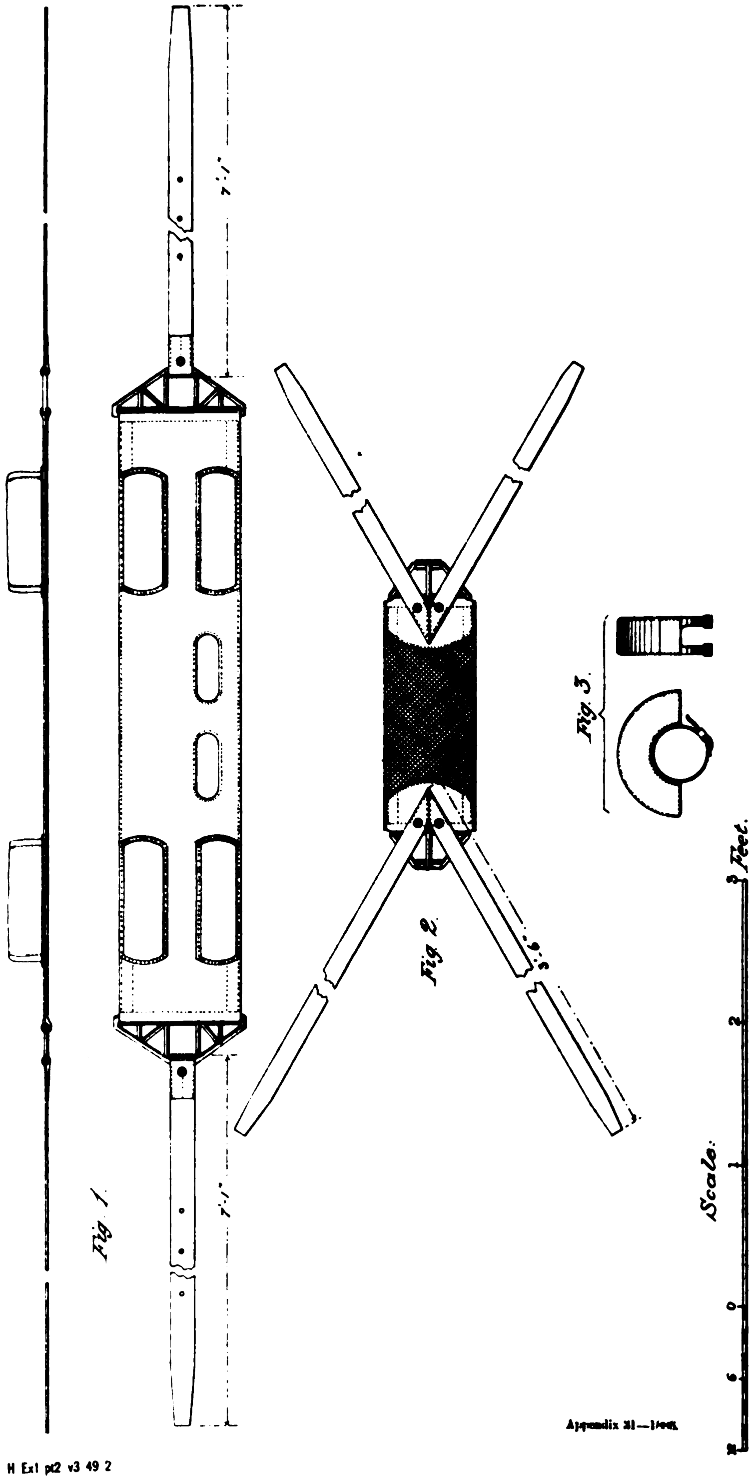


— HOTCHKISS MOUNTAIN GUN PACK. —



— HOTCHKISS MOUNTAIN GUN PACK. —

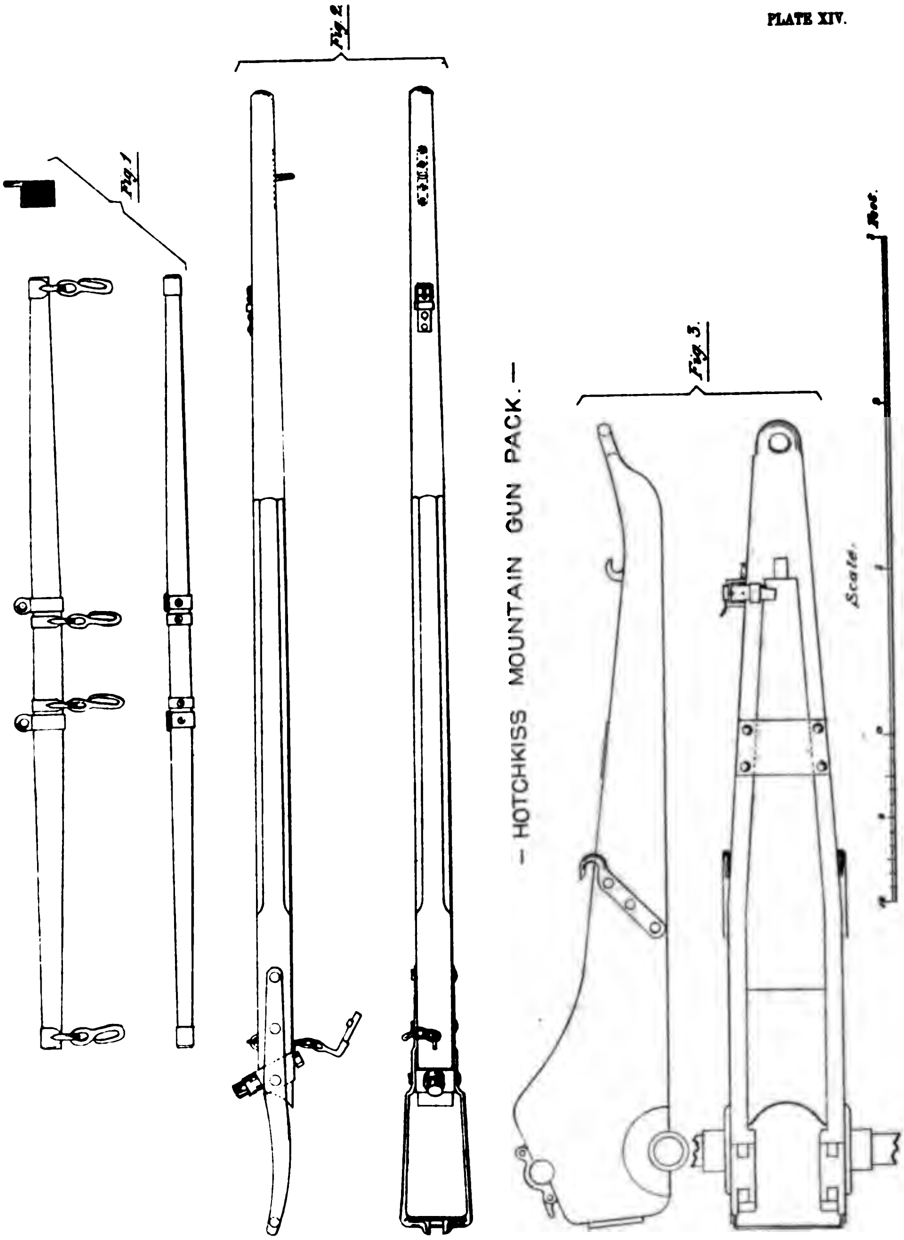
PLATE XIII.



— HOTCHKISS MOUNTAIN GUN PACK. —

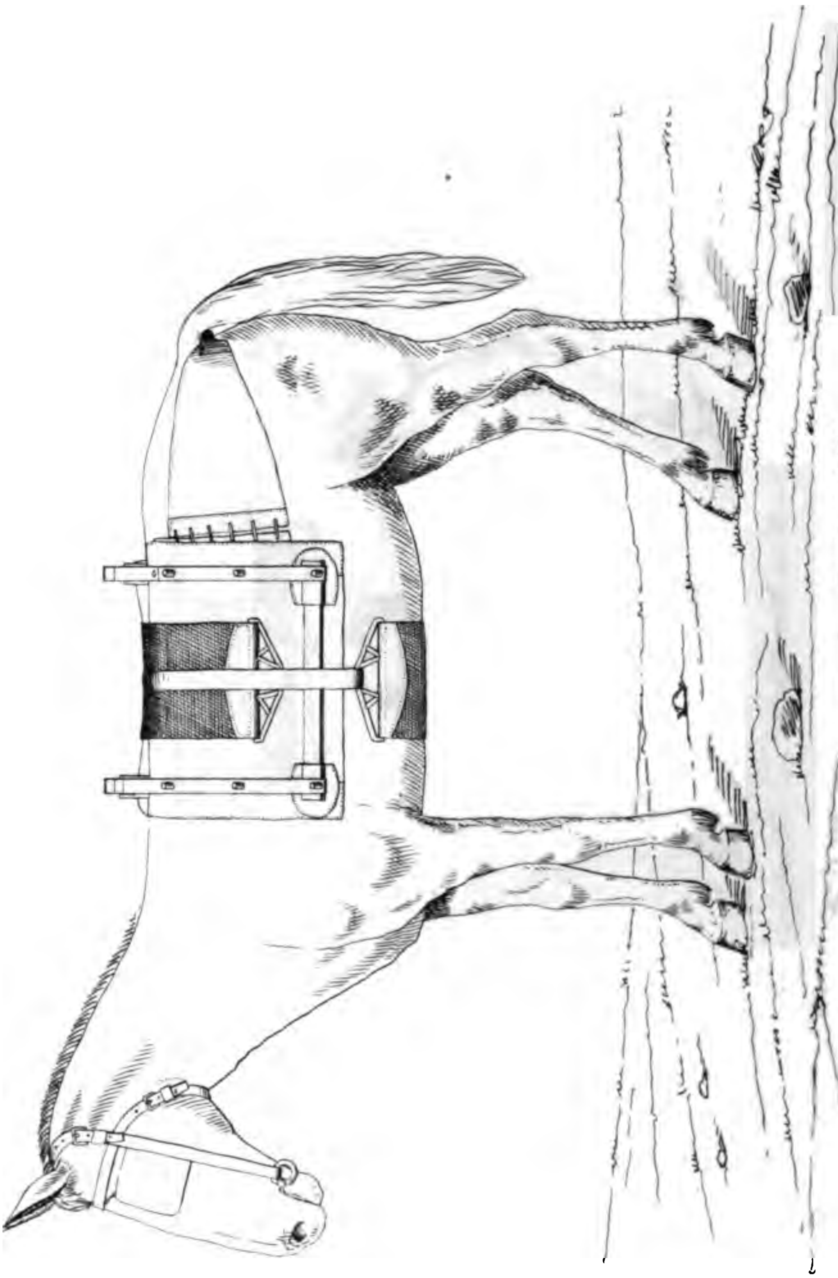
Appendix 31—Hotch.

PLATE XIV.



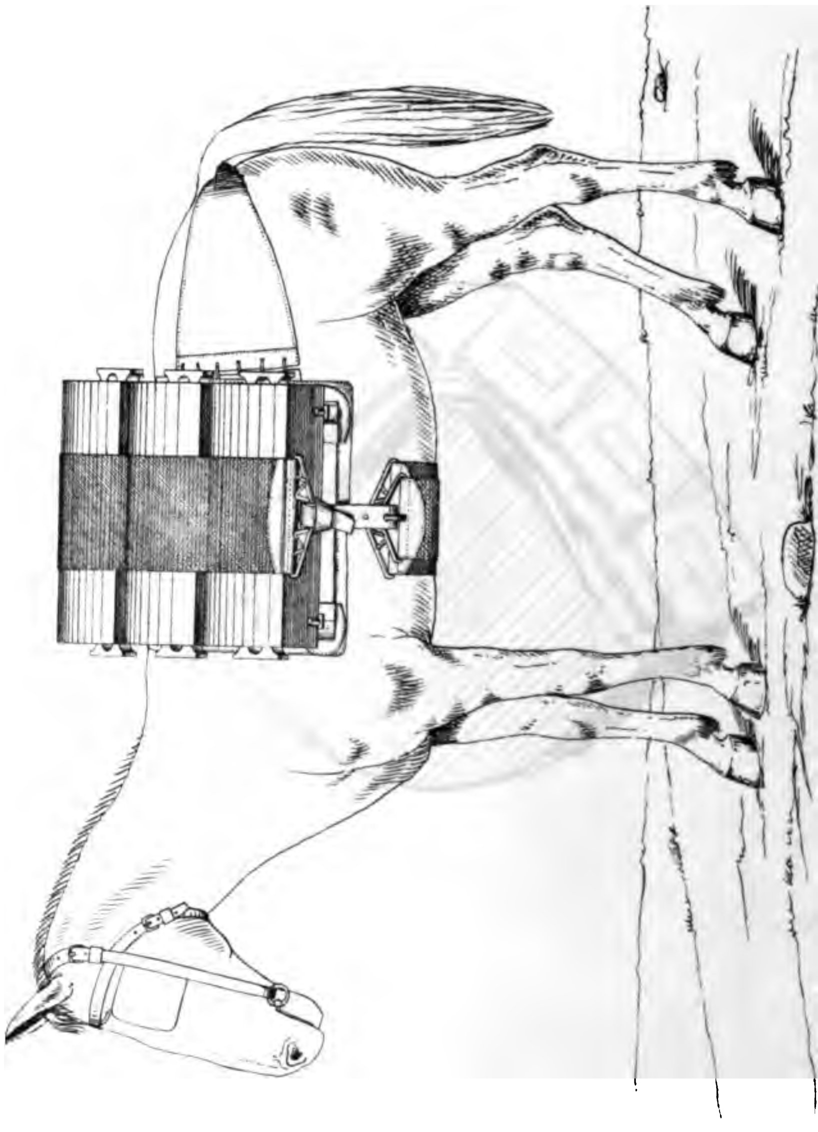
Appendix [illegible]

PLATE X.



— HOTCHKISS MOUNTAIN GUN PACK. —

Appendix 31—1886.



— HOTCHKISS MOUNTAIN GUN PACK. —

— HOTCHKISS MOUNTAIN GUN PACK.—

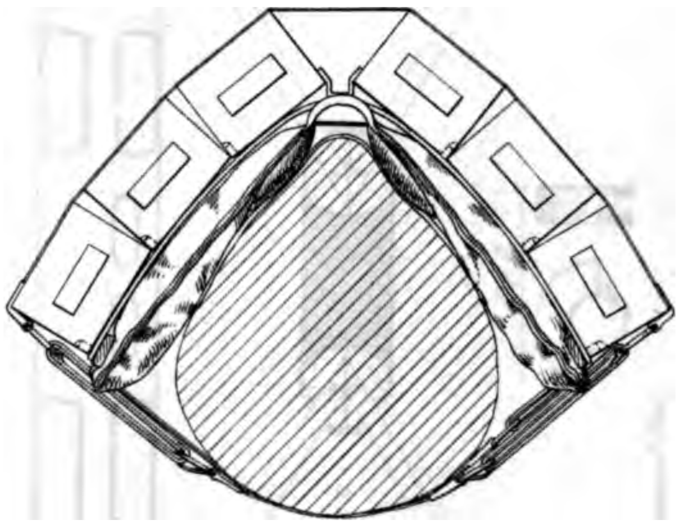
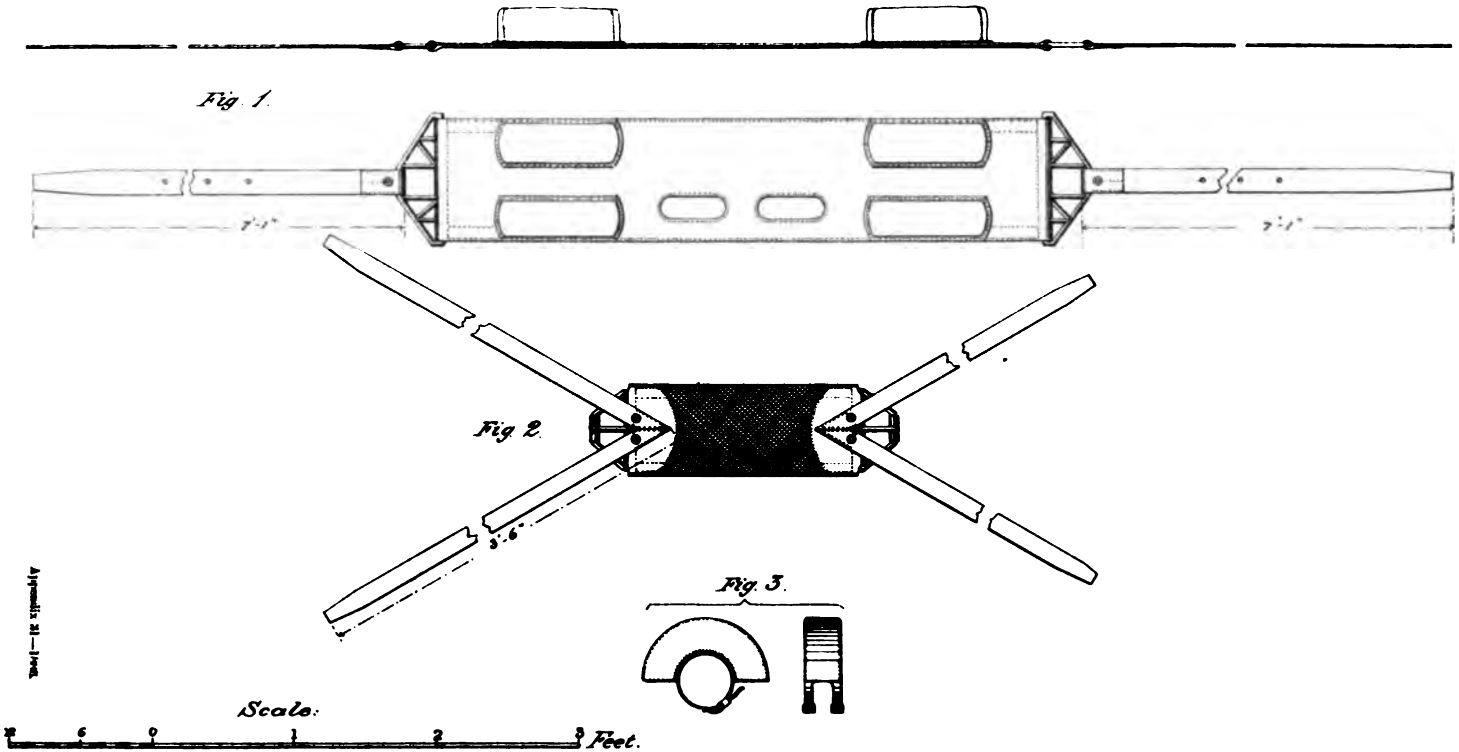


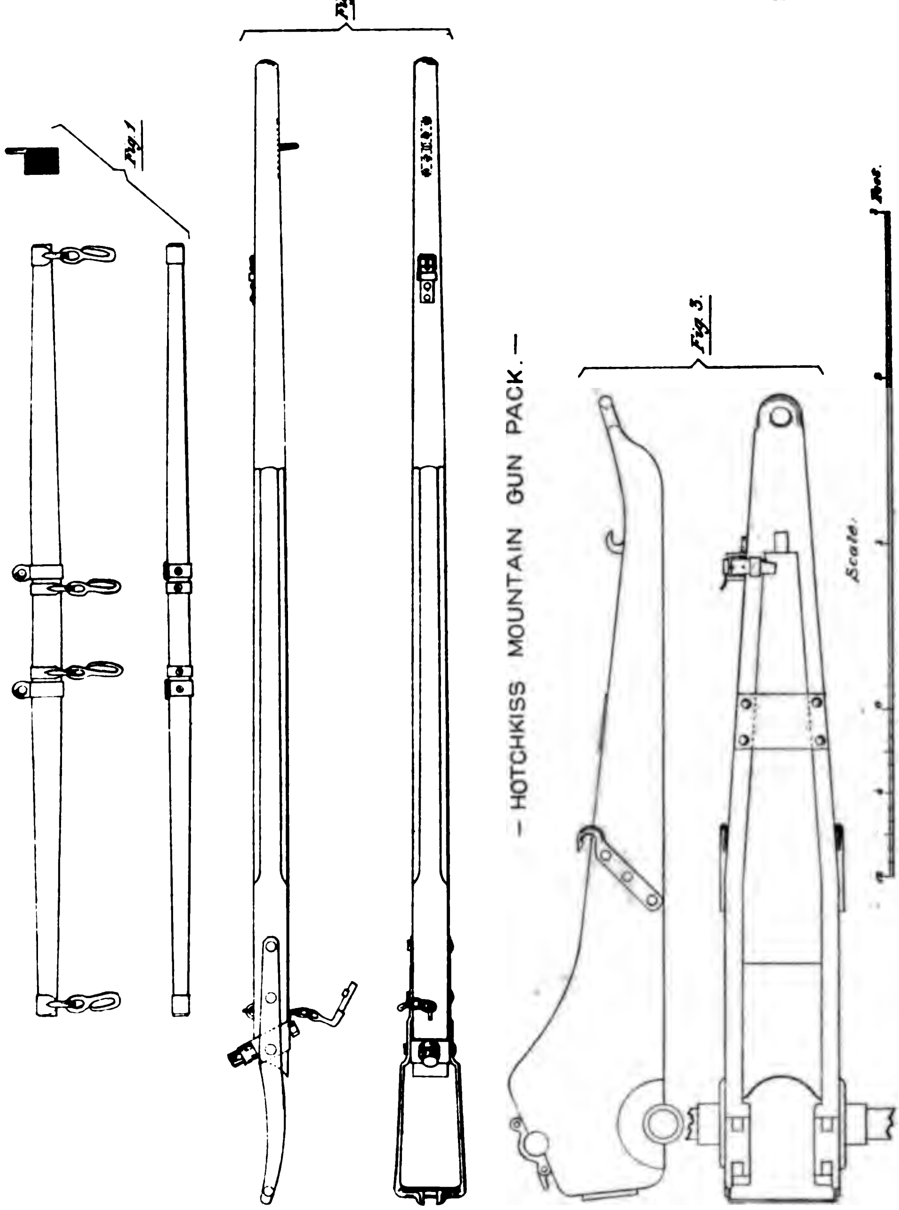
PLATE XIII.



— HOTCHKISS MOUNTAIN GUN PACK. —

Appendix 31—1900.

PLATE XIV.



Appendix 33—[illegible]

PLATE XV.

Fig 3

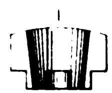


Fig 4

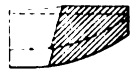


Fig 5

Fig 2

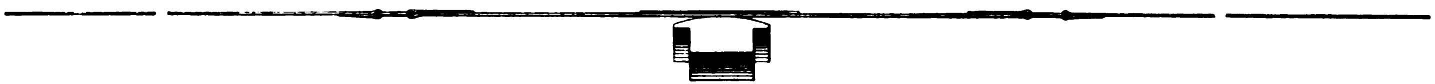
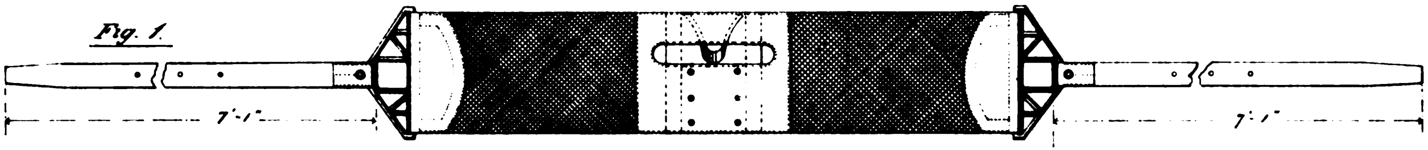
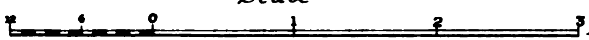


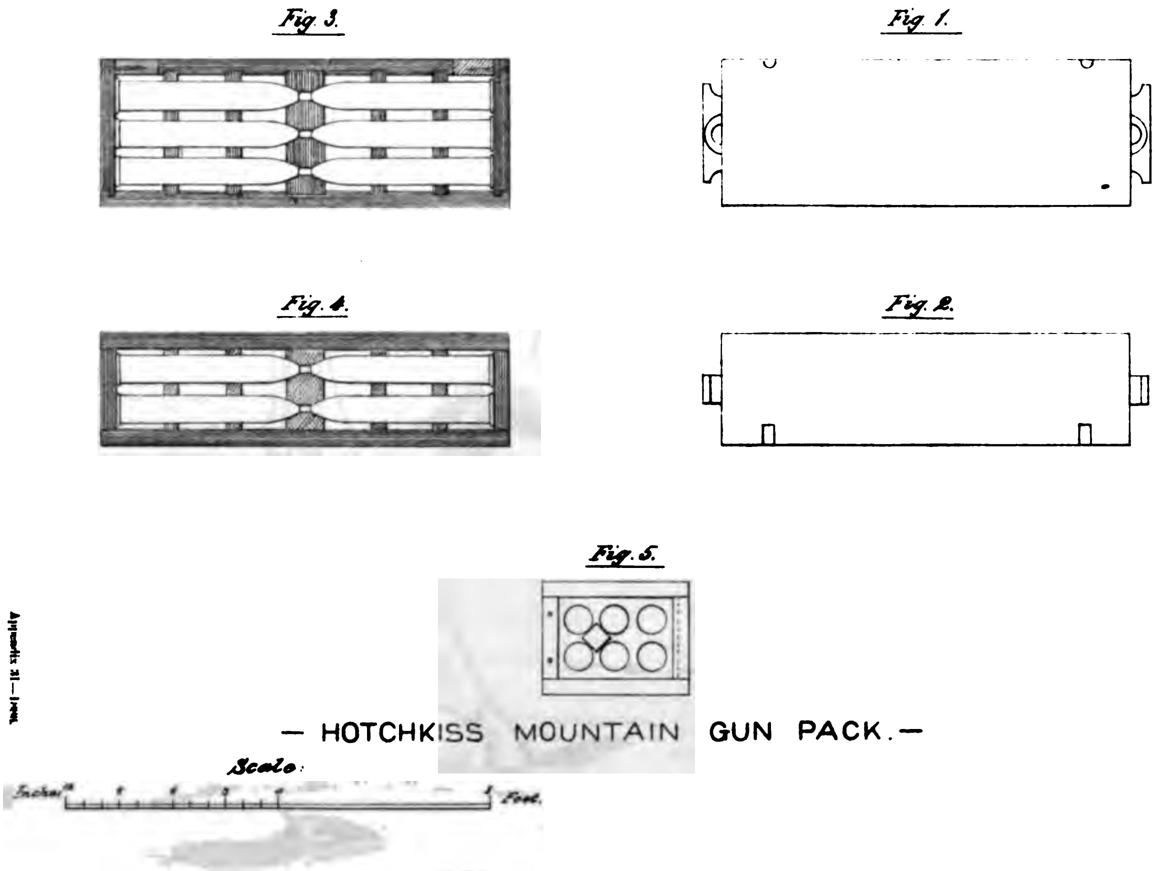
Fig. 1.



— HOTCHKISS MOUNTAIN GUN PACK.—

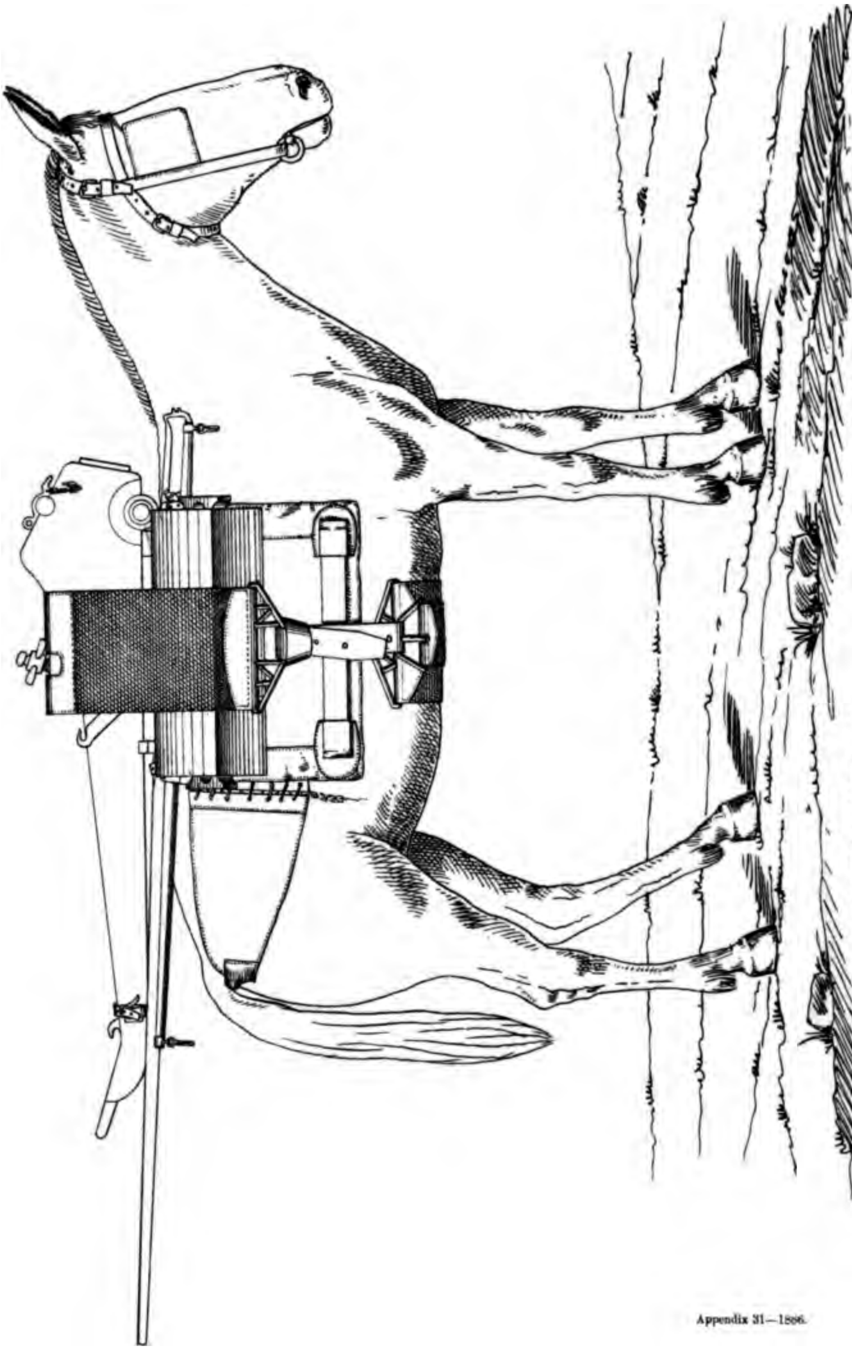
Scale.





— HOTCHKISS MOUNTAIN GUN PACK.—

PLATE XVII



— HOTCHKISS MOUNTAIN GUN PACK. —

APPENDIX 32.

REPORT OF PRINCIPAL OPERATIONS AT CHEYENNE ORDNANCE DEPOT DURING THE FISCAL YEAR ENDED JUNE 30, 1886.

BY LIEUT. O. B. MITCHAM, ORDNANCE DEPARTMENT.

CHEYENNE ORDNANCE DEPOT, WYOMING,
OFFICE CHIEF ORDNANCE OFFICER,
DEPARTMENT OF THE PLATTE,
August 18, 1886.

SIR: I have the honor to make the following report of the operations of this depot during the last fiscal year. The work done here consists of the receiving and issuing of ordnance and ordnance stores, of the rebrowning and repair of Springfield rifles and carbines turned in by troops serving in the department, and of the cleaning and repair of side lines, canteens, &c. The average number of enlisted men of the Ordnance Department on duty here during the year has been six, though seven is the authorized strength; the average number of men detailed upon extra duty at the depot has been eight, and the amount disbursed for their extra-duty pay was $1,180.45; in addition there has been expended at posts in the department during the year for such pay the sum of $11.90. During the year the receipts and issues have been as follows:

	Receipts.	Issues.
Third quarter of 1885	33	140
Fourth quarter of 1885	48	111
First quarter of 1886	106	195
Second quarter of 1886	60	101
	247	547

The work done (repairs, &c.) has been as follows:

REPAIRED AND REBROWNED.

484 Springfield rifles, model of 1873.
68 Springfield carbines, model of 1873.
2 Springfield shot-guns.
873 bayonets.

CLEANED AND REPAIRED.

193 side lines.
3 saddle-bags, O. M. No. 18.
6 hunting-knives.
6 hunting-knife scabbards.
200 bayonet scabbards.
7 Colts revolvers.
1 stitching-horse.
976 canteens re-covered and adapted to the leather strap.

FABRICATED.

6 stirrups with hoods and guidon sockets.

REPAIRED AND PAINTED.

1 spring wagon.

OVERHAULED AND CLEANED.

2 Gatling guns, caliber 45 (short barrel).
2 Gatling guns, caliber 45 (long barrel).
41 Schofield, Smith & Wesson revolvers.
23 carbine slings.
25 thongs and brushwipers.

MANUFACTURED.

6 arm-chests.
30 temporary frames for Laidley targets.

During the month of December, 1885, little or no work beyond the ordinary issues and receipts was done, the entire force being engaged in cleaning and rearranging the storehouses and shops on account of repairs being made to the buildings by the Quartermaster Department.

All stores furnished by the Department have been very satisfactory. It is thought that the new model hooded stirrups, carbine boots and straps, and saber straps, recently issued, will fully meet the requirements of the service.

The front and rear sights of the rifle model of 1884 have failed to give satisfaction. The front sight is too high and too thin, being liable to injury in service when used without the cover, and it is not sufficiently outlined in aiming to be readily seen in all conditions of the atmosphere. With regard to the rear sight, the leaf-slide binding screw fails to hold the leaf-slide, and the shock of the discharge causes the slide to slip or jump, almost invariably up, requiring constant attention on the part of the firer, and being the cause of much inaccuracy at target practice and in rapid firing. The front base screw (rear sight-screw front) fails to hold the movable or windage base, and the latter soon works loose; this defect is in part remedied either by filing off the base of the screw, thus shortening it, or by inserting a small copper washer under the head of the screw to give a yielding bearing surface. It is believed that a V-shaped notch would be much more satisfactory on the buck-horn open sight than the present semicircular notch. The aperture or peep-sights on the leaf-slide are entirely too large, and are, in fact, no peep-sight at all; almost invariably company commanders have them closed with wooden pins to avoid possible sources of error in aiming.

The sight, as a whole, in its present design is structurally weak and unsuited for a service sight.

Reports have also been received at this office that with some of the rod-bayonet rifles, model of 1884, the attachments fail to hold the bayonet in position, allowing it to jump out an inch or two at each discharge of the rifle.

I have before recommended the issue of brass shells for reloading rifle and carbine ammunition, and would respectfully renew the recommendation. The attention of the Chief of Ordnance is invited to the many advantages of a self-registering target. If a suitable one, as regards simplicity and economy, could be devised and issued by the Ordnance Department, such a target would materially lighten the work of all concerned on the target range, and would set at rest any doubts regarding the scores or standing of companies and troops in target practice.

Very respectfully, your obedient servant,

O. B. MITCHAM,
Lieut. of Ordnance, Chief Ordnance Officer,
Department Platte, Commanding,

The CHIEF OF ORDNANCE,
Washington, D. C.

APPENDIX 33.

CAPTAIN A. H. RUSSELL'S HYDRAULIC BUFFER.

(2 plates.)

VANCOUVER BARRACKS ORDNANCE DEPOT,
Vancouver, W. T., July 21, 1886.

SIR: In view of the claims made by J. Vavasseur to the invention of the valved piston-head for hydraulic buffers used to check the recoil of heavy guns, I have the honor to submit my own claims to this invention, with request for the publication of this letter, with its accompanying drawing, and of my letter to the Chief of Ordnance, December 16, 1875 (including indorsements), with its inclosed description and drawing of such device, dated November 26, 1875.

This official publication is now desired because the report of the Board on Fortifications and other Defenses, 1885 (Appendix 4, report of sixth committee), commending this device, attributes it to Vavasseur, the unpublished record in the Ordnance Office having apparently escaped attention.

Description was sent to the Ordnance Office in January, 1876, with the letter of December 16, 1875, signed by me as Second Lieutenant, Third Cavalry, but as I was then notified that the device would not be tested, I omitted to pay the final fee which was alone needed to complete the patent, my claims to priority of invention being, however, fully recognized by the Patent Office.

I have no money interest in the question, as my claim to patent is outlawed. I desire only professional recognition.

I claim that the use of the valved piston-head is free to the United States Government without reference to Vavasseur's patent. His English patent was taken out August 27, 1877, nearly two years after my device was well known to professional men in this country, and a year and a half after my own claims had been allowed by the United States Patent Office, and full description had been sent to the Ordnance Department. His United States patent was issued August 28, 1883, six years after his English patent, though the record of my previous claim had been for eight years on file in the Patent Office, where it still remains unquestioned.

The following are the claims allowed me by the Patent Office, and the inclosed plate shows drawings submitted with the application.

I claim as of my own invention—

(1) As an improvement in hydraulic buffers, the combination, substantially as hereinbefore set forth, of a cylinder, a piston-rod reciprocating therein, and a supple-

mentary perforated piston-head turning relatively thereto, to vary the area of the water-way through the piston-head.

(2) The combination, substantially as hereinbefore set forth, of the cylinder, the turning sectional piston-head, and its guides.

Very respectfully, your obedient servant,

A. H. RUSSELL,
Captain of Ordnance.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.

WEST POINT, N. Y., *December* 16, 1875.

SIR: I inclose herewith the description of a modification in hydraulic buffers for use with heavy guns. By this device the size of apertures in the piston-head can be adjusted from without by a rotation of the cylinder or of the piston-rod; or they can be made to vary during the recoil and thereby produce a constantly increasing resistance as in the pneumatic buffer.

I would respectfully solicit for this modification careful examination with a view to its reference to the Board of Experiment on heavy guns for trial and report.

Very respectfully, your obedient servant,

A. H. RUSSELL,
Second Lieutenant, Third United States Cavalry.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.

[First indorsement.]

ORDNANCE OFFICE, *January* 12, 1876.

Respectfully referred to the Board on Experimental Guns, &c., New York City, for examination and report.

S. V. BENÉT,
Brigadier-General, Chief of Ordnance.

[Second indorsement.]

BOARD ON EXPERIMENTAL GUNS, ETC.,
UNITED STATES ORDNANCE AGENCY,
New York, March 29, 1876.

Respectfully returned to the Chief of Ordnance, U. S. A., with the following extract from the proceedings of the Board of the 27th instant:

* * * * * * *

In view of the present satisfactory working of the hydraulic buffer, it is not deemed important at this juncture to test any devices looking to its improvement.

S. CRISPIN,
Brevet Colonel, United States Army,
Lieutenant-Colonel of Ordnance.

Modification of piston-head in the hydraulic buffer for the service of heavy guns.

In connection with the ordinary piston-head of the hydraulic buffer, which is a solid disk perforated with holes for the passage of the liquid in the cylinder (see figures 1 and 2), a second disk is employed, perforated in like manner and free to revolve around the piston-rod. (See *r'* in figures.)

The apertures can be made to open or close to any desired degree by turning either disk, or both, and thus the resistance of the liquid to the motion of the piston can be varied as circumstances may require.

Upon the circumference of the additional disk one or more projections (*c*) or slots (*c'*) are made, fitting to grooves or ribs (*d*, figure 2) upon the interior surface of the cylinder.

These grooves or ribs are straight or spiral; and in either case the relative positions of the disks can be changed and the size of aperture varied, whether the piston is at rest or in motion, by turning either the rod or cylinder, or both.

At *W* the piston-rod is shaped to receive a wrench or perforated to receive a bar, by which the rod and its disk can be turned from the outside. Marks *m*, *m'*, *m''* on the piston-rod, and cylinder or framework (figure 2) indicate the relative positions of the disks and the width of aperture in the piston. The piston-rod is clamped to the frame-work *H*, or to a bushing made to slide in a slot cut vertically in the frame.

When the grooves or ribs are spiral the second disk can be made to turn by simply moving the piston through the cylinder without turning the piston-rod or the cylinder.

By these modifications the apertures in the piston can be adjusted from outside the cylinder to correspond to any charge of powder or to any gun; or an increasing resistance to recoil can be produced by varying the apertures during the recoil, thus avoiding violent shock to the parts of the carriage.

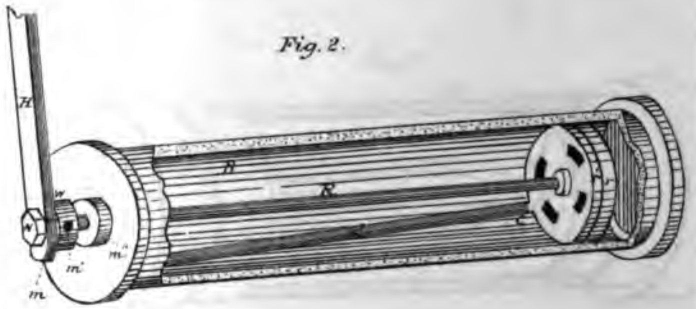
ANDREW H. RUSSELL,
Second Lieutenant, Third United States Cavalry.

NOVEMBER 26, 1875.

HYDRAULIC BUFFER

Fig. 1.

Fig. 2.

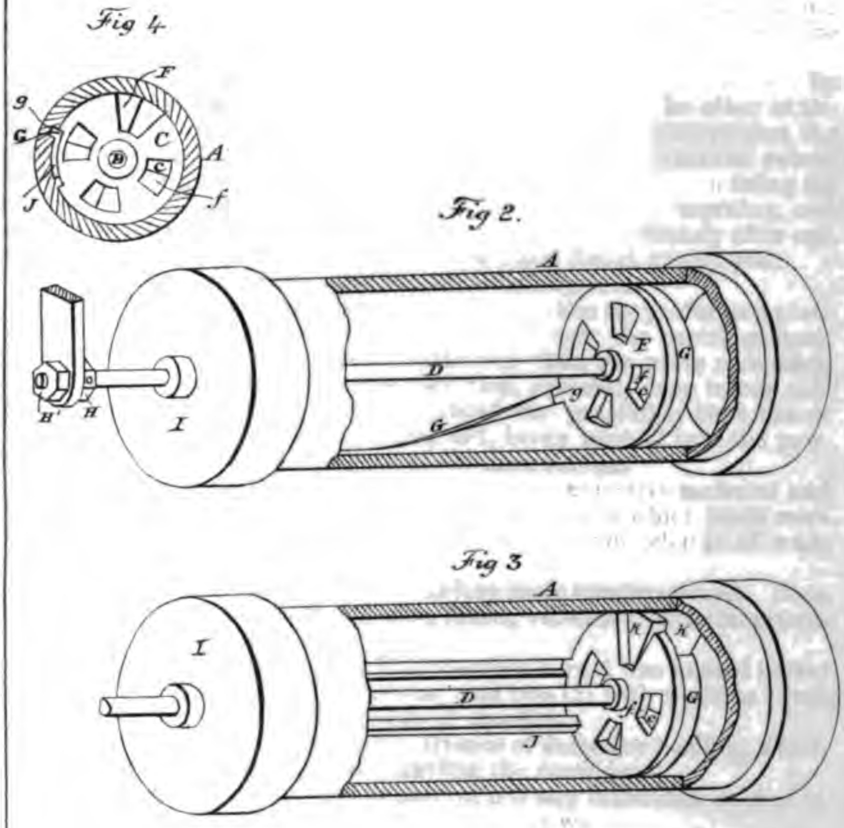


Appendix 33—1886.

PISTON BUFFER FOR ORDNANCE

COPY of DRAWING IN APPLICATION FOR PATENT "ALLOWED", JAN. 17. 1876.

To A. H. RUSSELL 2nd LIEUT. 3rd CAV. U.S.A.



APPENDIX 34.

REPORT OF TRIALS OF CARBINE CARTRIDGES.

BY CAPT. FRANK BAKER, ORDNANCE DEPARTMENT.

FRANKFORD ARSENAL, *May* 24, 1886.

SIR: In compliance with the instructions in your indorsement on my report of April 16, relative to failures to hit 500-yard target when firing for accuracy with carbine ammunition, I have the honor to submit the following report:

As the carbine (when the failures to hit occurred) was examined by Mr. Carr, in one case immediately after the shot and in the other at the close of the series, and found unchanged, it seemed conclusive that the trouble must be in the ammunition. In confirmation of this the velocities had not been as uniform as usual, while, on April 17, in firing for accuracy myself, one shot failed to reach the target in the morning, and one in the afternoon. The carbine was examined immediately after one miss and after the shot following the other, and found unchanged.

The cause was, therefore, sought at the loading-room.

It was noticed that, at the loading-machine, when the perforated plate filled with wads brings a charge of the latter over the cartridge case, the wads, made slightly smaller in diameter than the plate receptacle and cartridge case to facilitate the operation, generally drop to one side before being forced down. This indicated the possibility that one or more wads might go down edgewise, and, being pushed into the powder, seriously affect the uniformity of the ammunition.

An examination of 100 cartridges rejected for defective material and workmanship (not for loading) discovered five (5) in which wads were forced down edgewise, and one (1) in which the whole charge of wads was upset.

One hundred (100) cartridges from loading-room were examined. None imperfect. Cartridges remaining after taking velocities (with ununiform results) showed none imperfect.

One hundred (100) made April 17 (date when target was missed twice) discovered two (2) with wads edgewise and two (2) with wads so tilted as to displace a portion of the charge of powder.

These investigations show the occurrence of defective loading, which cannot be detected except by dismantling the cartridge.

The next step, therefore, was to ascertain if any difference existed in the performance of cartridges with and without wads.

Samples of the latter were loaded twice daily for comparison with the regular product, for velocity and accuracy. On account of the necessary shortening of the cartridge (with charge of 51 grains dried powder) only the powder-charging could be done in the loading-machine, the bullets being set down and the case crimped by a foot-press.

This was all done by the foreman of the loading-room, and the circumstances were as nearly identical with those under which machine cartridges were loaded as possible.

The first were loaded with .2 of an inch compression—about the same as in the regular cartridge—but gave a velocity of 1,161 feet and to approximate more closely to the daily work, a compression of 0.15 of an inch was tried, with satisfactory result. The comparison was continued until the cessation of manufacture of carbine ammunition, when 400 of each were set aside for further trial. The results are appended in detail, Tables I to X, inclusive.

Two series were fired for velocity, in one of which a wad was forced edgewise into the powder, the others being then pressed down, while the other series was carefully loaded with all the wads straight. The results are in Table XIII. They show great irregularity in velocity as result of defective placing of a wad. Furthermore, the wads sometimes stick to the bullet and accompany it to the 500 yards' target, which must be to the detriment of accuracy.

This fact was reported by me to the late Colonel Lyford during his command, and by his verbal authority attempts were made to improve the accuracy by various means, all looking to discarding all or most of the wads, while retaining the same cartridge length, but none gave much promise of success except the use of 500 grains bullet. The recoil, however, was increased to about the same as with the 70–405 cartridge, which had been objected to in service.

The desirability of dispensing with the wads has been recognized by all, and various devices have been tried, but mostly with view to retention of the regular length.

Lining the case with a paper cylinder and the use of a paper cap over the powder were suggested by Colonel Benton.

Cartridges without wads, the bullet being set down on 55 grains charge without compression (shortening the length 0.085 of an inch), were reported upon by Colonel Whittemore's order in June, 1877. The report by Captain Wright states as results "fair velocities, good practice, diminished pressures, and medium recoil." Some trouble was developed by the jamming of the breech-block, which was attributed either "to bad loading or high pressure developed by increased sluggage."

In October, 1884, Lieutenant MacNutt reported results of firing cartridges with and without wads for comparison, as follows:

VELOCITY.

Regular cartridges (45 shots), 1,139′.
Without wads (45 shots), 1,125′.

ACCURACY.

Regular cartridges: Radius of circle of shots, 0.90′, 0.87′, 0.85′. Mean, 0.87′.
Without wads: Radius of circle of shots, 0.67′, 0.82′, 0.88′. Mean, 0.79′.

The objection to simply doing away with the wads has been the desirability of having the cartridge fit the chamber as nearly as possible, and the injurious effects on accuracy likely to be caused by sensibly increasing the distance which the bullet must travel before engaging the cannelures in the rifling. All the records here, however, fail to substantiate the objection on score of accuracy, while reference to Report of Chief of Ordnance, 1873, p. 389, discovers a similar record.

In any event the loss in accuracy due to shortening the carbine cartridge seems more than made up by the gain due to absence of wads.

To recapitulate: The following with 51 grains of powder, dried, 0.15 of an inch compression, have been fired in comparison with the service ammunition for carbine, with results as given:

Targets of ten shots each.	Kind.	Radius of circle of shots.	Mean vertical deviation.
34	No wads.	0'.88	0'.623
40	Regular.	1'.10	0'.784

The following were fired, cleaning carbine after each second target:

8	No wads.	1'.01	0'.722
8	Regular.	1'.05	0'.773

Six targets were fired without cleaning carbine, with following results.

6	No wads.	0'.84	0'.569
6	Regular.	1'.01	0'.633

These results are conclusive, that the effect of the wads is to impair the accuracy in a marked degree, and, I think, demonstrate the practicability of dispensing with them.

Before concluding the experiments, it was determined to try cartridges loaded without wads, with 53 grains dried powder and 0.15 of an inch compression, as such are the shortest that can be machine-loaded and give a good crimp, without radical change in the method of inserting bullet. This length, 2.43 inches, allows 0.15 of an inch compression with 55 grains undried powder. The results were as follows: (See Table XI.)

	Feet.
Velocity, mean of 2 series, 16 shots	1,150
Radius of circle of shots, mean of 5 targets	.93
Mean vertical deviation	.703

An examination of any of the modified cartridges shows more compression on the exterior of the cylinder of the charge than on the interior, owing to the cup-shaped cavity in the base of the bullet (it will hold a grain of loose powder). I thought it possible that a bullet with a base like the 500 grains, giving a better seat and more uniform compression to the charge, might give better results. A trial, however, showed but little difference, and that in favor of the service (Table XII).

In view of these results, I would recommend that the wads be dispensed with in carbine cartridges.

I think 2.45 inches may be safely adopted as a maximum length for the cartridge, the powder charge to remain as at present (55 grains).

The changes necessitated would be comparatively slight.

With the hand-reloading tools a new loading-punch would be required to accommodate the diminished length of cartridge.

The bench-tools, as now made, will require 0.12 of an inch taken off the top surface of the lug-guide for loading-spindle, or a countersink to permit setting the spindle down to the required place. In those now in hands of troops the former change could probably be made with a file at the posts.

Some change would be required in the pasteboard box, but it would be slight.

Per contra, we will have a simpler and more accurate cartridge, while the cost of the wads will be saved and the services of two hands at the loading-machine dispensed with.

During the present fiscal year 14,071,850 wads have been made, at a cost of $703. One million nine hundred and fourteen thousand one hundred and seventy carbine cartridges have been made during the same time, in which the cost of using wads was about $239.

Samples of the proposed cartridge loaded on machine, with bench and hand tools, are herewith.

Respectfully submitted.

FRANK BAKER,
First Lieutenant of Ordnance.

N. B.—I. In connection with proposed devices for dispensing with the wads, reference should have been made to the trial of powder with sufficiently low gravemetric density to occupy the required volume in the case, reports upon which were made by Capt. Frank Heath and Mr. J. J. O'Reilly.

II. Several hundred of the proposed shortened cartridges have been fired in the Gatling gun without trouble. This is, however, about as short a cartridge as could be fired without difficulty.

TABLE I.—*Comparison of regular carbine cartridges.*

[Powder compression 0″.2 and carbine cartridges without wads; powder compression 0″.15, 81 grains powder; 405 grains bullet; April 24, 1886, a. m.]

	Velocities.				Accuracy.	
	Regular Le Boulengé.		Experimental Le Boulengé.		Radius of circle of shots.	
	No. 1.	No. 2.	No. 1.	No. 2.	Regular.	Experimental.
Prelim.	1132	1144	1142	1153	1.17	0″.68
Prelim.	1138	1144	1150	1158	1.08	
	1138	1143	1148	1143	Mean vertical deviation.	
	1134	1133	1146	1149	.930	.500
	1139	1147	1138	1142	.805	
	1138	1142	1140	1144	Experimental target made between regular targets.	
	1131	1132	1146	1148		
	1134	1133	1152	1158		
Av'ge,	1135.6	1138.3	1145	1147		
	1136.9		1146.1			
	Extreme variation.					
	15′		16′			

TABLE II.

[April 26, 1886, a. m.]

Velocities.				Accuracy.	
Regular Le Boulengé.		Experimental Le Boulengé.		Radius of circle of shots.	
No. 1.	No. 2.	No. 1.	No. 2.	Regular.	Experimental.
1166	1156	1140	1130	1.08 1.40	1.10
1140	1134	1137	1126		
1139	1138	1137	1129	Mean vertical deviation.	
1136	1132	1144	1134	.665	.910
1134	1130	1120	1122	.940	
1117	1102	1143	1136		
1150	1148	1130	1121		
1136	1130.6	1135	1124.6		
1133.3		1129.8			
Extreme variation.					
46′		24′			

[April 26, 1886, p. m.]

Velocities.				Accuracy.	
Regular Le Boulengé.		Experimental Le Boulengé.		Radius of circle of shots.	
No. 1.	No. 2.	No. 1.	No. 2.	Regular.	Experimental.
1152	1148	1162	1154		
1138	1130	1136	1128	.89	.75
1134	1129	1124	1127	1.14	
1136	1130	1146	1144	Mean vertical deviation.	
1138	1137	1146	1141	.510	.460
1134	1130	1142	1137	.960	
1138	1136	1149	1148		
1136.3	1132	1140.5	1137		
1134.1		1138.5			
Extreme variation.					
8′		22′			

TABLE III.

[April 27, 1886, a. m.]

Velocities.				Accuracy.	
Regular Le Boulengé.		Experimental Le Boulengé.		Radius of circle of shots.	
				Regular.	Experimental.
No. 1.	No. 2.	No. 1.	No. 2.	1.04	.80
1147	1138	1130	1125	1.10	
1137	1139	1132	1136		
1124	1126	1139	1134	Mean vertical deviation.	
1138	1140	1127	1128	.740	.510
1134	1134	1128	1128	.920	
1143	1145	1126	1128		
1124	1127	1120	1120		
1133.3	1135.1	1128.6	1129		
1134.2		1128.8			
Extreme variation.					
19'		19'			

[April 27, 1886, p. m.]

Velocities.				Accuracy.	
Regular Le Boulengé.		Experimental Le Boulengé.		Radius of circle of shots.	
No. 1.	No. 2.	No. 1.	No. 2.	Regular.	Experimental.
1147	1146	1126	1126		
1140	1144	1137	1141		
1134	1136	1148	1150	1.04	1.24
1129	1132	1142	1144	1.49	
1130	1129	1122	1120	Mean vertical deviation.	
1137	1140	1124	1125	.790	1.06
1137	1142	1119	1121	1.11	
1134.5	1137.1	1132	1133.5		
1135.8		1132.7			
Extreme variation.					
15'		30'			

TABLE IV.

[April 28, 1886, a. m.]

Velocities.				Accuracy.	
Regular Le Boulengé.		Experimental Le Boulengé.		Radius of circle of shots.	
				Regular.	Experimental.
No. 1.	No. 2.	No. 1.	No. 2.	1.04	.91
1134	1130	1143	1147	1.04	
1134	1138	1145	1152	Mean vertical deviation.	
1123	1127	1146	1136	.785	.590
1129	1132	1143	1144	.685	
1134	1143	1146	1147		
1103	1101	1141	1141		
1128	1122	1143	1148		
1125	1127.1	1144	1145		
1126		1144.5			
Extreme variation.					
42′		14′			

TABLE V.

[April 30, 1886, a. m.]

Velocities.				Accuracy.	
Regular Le Boulengé.		Experimental Le Boulengé.		Radius of circle of shots.	
				Regular.	Experimental.
No. 1.	No. 2.	No. 1.	No. 2.	1.74	.64
1154	1153	1165	1158	1.44	.85
1155	1156	1140	1136	Mean vertical deviation.	
1146	1154	1152	1144	1.44	.455
1122	1127	1148	1154	.9	.615
1136	1136	1146	1153		
1120	1128	1138	1141		
1126	1123	1140	1146		
1234.1	1137	1144	1145.6		
1135.8		1144.8			
Extreme variation.					
35′		18′			

TABLE VI.

[May 1, 1886, a. m.]

Velocities.				Accuracy.	
Regular Le Boulengé.		Experimental Le Boulengé.		Radius of circle of shots.	
				Regular.	Experimental.
No. 1.	No. 2.	No. 3.	No. 4.	.96	.73
1132	1128	1164	1158		
1140 1136 1132 1118 1125 1139	1135 1133 1126 1116 1127 1134	1134 1138 1133 1129 1130 1140	1130 1142 1134 1126 1143 1134	Mean vertical deviation.	
				.875	.590
1131.6	1128.5	1134	1134.8		
1130		1134.4			
Extreme variation.					
22′		17′			

TABLE VII.

May 3, 1866, a. m.]

Velocities.			
Regular Le Boulengé.		Experimental Le Boulengé.	
No. 1.	No. 2.	No. 1.	No. 2.
1140	1134	1140	1134
1131	1134	1136	1134
1133	1133	1142	1148
1132	1132	1134	1137
1116	1124	1130	1132
1122	1126	1134	1139
1134	1142	1133	1144
1128	1131.8	1134.8	1139
1129.9		1136.9	
Extreme variation.			
18′		16′	

Accuracy.	
Radius of circle of shots.	
Regular.	Experimental.
1.11	1.06
.94	1.05
1.76	1.07
.69	1.21
1.03	1.04
.96	1.09
.97	.73
.93	.83
8.39	8.08
1.05	1.01
Mean vertical deviation.	
Regular.	Experimental.
.910	.920
.700	.720
1.365	.685
.480	.900
.640	.755
.560	.720
.785	.560
.745	.515
6.185	5.775
.773.1 (*)	.721.7

*Gun cleaned after each two targets.

[May 3, 1866, p. m.]

1134	1130	1164	1164
1133	1138	1140	1142
1116	1118	1150	1158
1121	1132	1141	1148
1128	1132	1140	1148
1135	1143	1136	1142
1131	1139	1134	1143
1127	1133	1140	1143.4
1130		1141.7	
Extreme variation.			
25′		16′	

TABLE VIII.

[May 4, 1896, a. m.]

Velocities.				Accuracy.	
Regular Le Boulengé.		Experimental Le Boulengé.		Radius of circle of shots.	
No. 1.	No. 2.	No. 1.	No. 2.	Regular.	Experimental.
1136	1138	1127	1126	.81	.85
				.84	.80
				1.20	.73
				1.08	.66
				.84	.97
				1.32	1.05
				6.09	5.06
				1.015	.84
1137	1127	1154	1152	Mean vertical deviation.	
1136	1138	1146	1152	.635	.590
1130	1127	1138	1140	.480	.525
1136	1134	1136	1134	.895	.535
1128	1124	1138	1141	.505	.450
1132	1130	1137	1144	.515	.655
				.770	.660
				3.800	3.415
				.633	.569
1133.1	1130	1141.5	1143.9	Gun cleaned after each series of six.	
1131.5		1142.7			
Extreme variation.					
14′		18′			

[May 4, 1896, p. m.]

Velocities.			
Regular Le Boulengé.		Experimental Le Boulengé.	
No. 1.	No. 2.	No. 1.	No. 2.
1134	1134	1142	1144
1133	1134	1158	1152
1136	1136	1136	1138
1138	1133	1136	1130
1137	1130	1143	1139
1142	1138	1146	1148
1140	1139	1136	1138
1137.6	1135	1142.5	1140.8
1136.3		1141.6	
Extreme variation.			
9′		22′	

TABLE IX.

[May 5, 1896.]

Velocities.				Accuracy.	
Regular Le Boulengé.		Experimental Le Boulengé.		Radius of circle of shots.	
No. 1.	No. 2.	No. 1.	No. 2.	Regular.	Experimental.
1145	1137	1146	1143	1.47	.72
1139	1141	1134	1135	.88	.95
1134	1138	1130	1134	1.08	.79
1137	1132	1130	1142	.79	.97
1140	1139	1150	1152	4.22	3.43
1141	1138	1136	1134	1.05	.86
1141	1136	1134	1137	Mean vertical deviation.	
1138.6	1137.3	1137.1	1139	.845	.535
1137.9		1138		.640	.690
Extreme variation.				.670	.440
9'		20'		.500	.680
				2.655	2.345
				.664	.586

[May 6, 1896.]

				Accuracy.	
				Radius of circle of shots.	
1150	1145	1147	1138		
1146	1138	1144	1137	1.44	.88
1128	1124	1138	1130	.70	1.03
1131	1127	1148	1144	1.07	.62
1129	1122	1135	1126	1.12	.88
1135	1132	1140	1132	4.33	3.41
1126	1123	1148	1138	1.08	.85
1132.5	1176.6	1142.1	1134.5	Mean vertical deviation.	
1130		1138.3		1.125	.615
Extreme variation.				.485	.801
20'		18'		.720	.385
				.930	.505
				3.260	2.306
				.815	.576

TABLE X.

[May 7, 1896.]

Velocities.				Accuracy.	
Regular Le Boulengé.		Experimental Le Boulengé.		Radius of circle of shots.	
				Regular.	Experimental.
No. 1.	No. 2.	No. 1.	No. 2.	1.05 1.00 1.19	.67 .67 .91
No velocities taken.				3.24	2.25
				1.08	.75
				Mean vertical deviation.	
				.700 .850 .840	.340 .550 .750
				2.390	1.640
				.796	.546

TABLE XI.—*Carbine cartridges.*

[Machine loaded. No wads. Compression—0".15. Powder, dried—53 grains. Bullet—405 grains. May 13, 1886.]

Velocities.		Accuracy.
Le Boulengé.		Radius of circle of shots.
No. 1.	No. 2.	.67
1164	1158	.52
1148	1150	.81
		1.03
1147	1142	1.63
1160	1158	Av.. 93.1
1148	1142	Mean vertical deviation.
1163	1154	.530
		.270
1161	1158	.675
		.750
1154	1146	1.290
1155.3	1150	Av. .703
1152.6		

[May 12, 1886.]

1181	1176	
1169	1168	
1144	1148	
1148	1136	
1154	1138	
1154	1151	
1132	1143	
1159	1155	
1154	1154	
1149	1134	
1164	1160	
1151	1132	
1150.9	1145.1	
1148		

TABLE XII.—*Carbine cartridges.*

Machine loaded. No wads. Dished-base bullet. Powder, dried—58 grains. Bullet—[illegible] grains.

[May 14, 1886.]

Dished base bullet.

Velocities. Le Boulengé.		Accuracy.	
		Radius of circle of shots.	
No. 1.	No. 2.	Regular bullet.	Dished base bullet.
		.81	1.08
		.99	.92
1163	1152	.75	.57
		.81	.93
		.65	.91
1124	1127	4.01	4.41
		.80	.88
1148	1144		
1155	1154		
1143	1143	Mean vertical deviation.	
		.550	.550
1145	1146	.695	.685
		.500	.385
		.630	.730
1134	1135	.455	.455
		2.830	2.805
1150	1152	.566	.561
1145.8	1145.7		
1145.75			

[May 15, 1886.]

		Accuracy.
1180	1176	Dished base bullet.
1148	1145	Radius of circle of shots.
		.53
		.74
1166	1158	1.19
1156	1154	.87
		.65
1149	1151	.796
1146	1148	Mean vertical deviation.
		.320
1153	1146	.400
		.685
		.535
1148	1144	.490
1153	1150.1	.486
1151.5		

TABLE XIII.—*Comparison for velocity between carbine cartridges, one wad inserted edgewise, and those in which all wads were properly loaded.*

Regular La Boulengé.		One wad edgewise, La Boulengé.	
No. 1.	No. 2.	No. 1.	No. 2.
	1136	1128	1132
1128 1124 1137 1124 1134 1140 1144	1134 1127 1137 1132 1133 1136 1132	1113 1104 1136 1128 1119 1133 1126	1124 1119 1136 1127 1114 1128 1134
1133	1133	1122	1126
		1124	
Extreme variation.			
20′		32′	

SUMMARY OF TARGETS IN TABLES I TO X.

Date.	Radius of circle of shots.		Mean vertical deviation.	
	Regular.	Experimental.	Regular.	Experimental.
Apr. 24	1.17 1.08	.68	.930 .805	.500
Apr. 26	1.08 1.40 .89 1.14	1.10 .75	.665 .940 .510 .960	.910 .460
Apr. 27	1.04 1.10 1.04 1.49	.80 1.24	.740 .920 .790 1.110	.510 1.060
Apr. 28	1.04 1.04	.91	.785 .685	.590
Apr. 30	1.74 1.44	.64 .85	1.440 .900	.455 .615
May 1	.96	.73	.875	.590
May 3	1.11 .94 1.76 .69 1.03 .96 .97 .93	1.06 1.05 1.07 1.21 1.04 1.09 .73 .83	.910 .700 1.365 .480 .640 .560 .785 .745	.920 .720 .685 .900 .755 .720 .560 .515
May 4	.81 .84 1.20 1.08 .84 1.32	.85 .80 .72 .66 .97 1.05	.635 .480 .895 .505 .515 .770	.590 .525 .585 .450 .655 .660
May 5	1.47 .88 1.08 .79	.72 .95 .79 .97	.845 .640 .670 .500	.535 .690 .440 .680
May 6	1.44 .70 1.07 1.12	.83 1.03 .62 .93	1.125 .485 .720 .930	.615 .801 .385 .505
May 7	1.05 1.00 1.19	.67 .67 .91	.700 .850 .840	.340 .550 .750
	43.92	29.92	31.345	21.171
	1.098	.88	.7836	.6227

APPENDIX 35.

SUMMARY OF REPORTS ON MAGAZINE RIFLES ISSUED FOR TRIAL IN SERVICE.

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, D. C., December 15, 1885.

SIR: I have the honor to transmit herewith a tabular statement of the results reached in the trial of a number of each of the magazine rifles issued to the troops. These guns—the Lee, Chaffee-Reece, and Hotchkiss—were recommended for trial, in the order named, by a board of officers convened in 1881 under authority of law, and were distributed to the Army for the purpose by the Lieutenant-General of the Army.

The reports from 149 companies have been received, examined, and tabulated, and the results are as follows:

Comparing the three magazine guns with each other, the reports are:

For the Lee, 55; Chaffee-Reece, 14; Hotchkiss, 26. As magazine guns, therefore, the reports are largely in favor of the Lee.

Comparing the magazine guns with each other and with the Springfield service rifle as *single loaders*, the preference is for the Springfield, as follows: For the Lee, 5; Chaffee-Reece, 0; Hotchkiss, 1; Springfield, 21.

Comparing the magazine guns and the Springfield for *all* uses, the preference is: For the Lee, 10; Chaffee-Reece, 3; Hotchkiss, 4, and the Springfield, 46; being largely in favor of the Springfield.

In the column of objections in the tabular statement will be found a brief of the objections given in each report.

After a careful consideration of these reports, I am satisfied that neither of these magazine guns should be adopted and substituted for the Springfield rifle as the arm for the service.

I have been and am an advocate for a magazine gun, but it would seem the part of wisdom to postpone for the present any further efforts towards the adoption of a suitable magazine arm for the service. The Springfield rifle gives such general satisfaction to the Army that we can safely wait a reasonable time for further developments of magazine systems.

Very respectfully, your obedient servant,

S. V. BENÉT,
Brigadier-General, Chief of Ordnance.

The SECRETARY OF WAR.

SUMMARY OF REPORTS ON MAGAZINE

Division.	Department.	Issued to— Regiment, company, &c.	Arm on trial and reported on.*	Magazine guns compared with each other. Preference. Lee.	Chaffee-Reece.	Hotchkiss.	Magazine guns compared with service rifle. Preference. As single loader. Lee.	Chaffee-Reece.	Hotchkiss.	Service.	For all uses. Lee.	Chaffee-Reece.	Hotchkiss.	Service.	Remarks.
The Pacific.	California.	Co. A, 1st Art	*H.*, Lee, C.-R.			1									No comparison with service; gives no strong reasons.
		Co. B, 1st Art	*Lee*, C.-R., H	1											Favors Lee strongly, C.-R. second, H. third; no comparison with service.
		Co. C, 1st Art	do	1						1					H. second, C.-R. third
		Co. H, 1st Art	*H.*, Lee, C.-R.	1						1					do
		Co. A, 2d Cav	*Lee*, C.-R., H	1			1				1				
		Co. K, 2d Cav	*C.-R.*, Lee, H							1				1	Lee and H. better magazine guns; no distinct preference expressed.
		Co. C, 8th Inf	*Lee*, H., C.-R			1								1	C. R. second, Lee third; service, perfect military arm.
		Co. H, 8th Inf	*C.-R.*, H., Lee	1										1	
		Co. K, 8th Inf	*H.*, Lee, C.-R												No comparison with service; no strong reasons.
			Total	5	0	2	1	0	0	3	1	0	0	3	
	Arizona.	Co. A, 4th Cav	*H*												No report; in field against hostile Indians.
		Co. F, 4th Cav	*Lee*												do
		Co. H, 4th Cav													do
		Co. A, 10th Cav	*C.-R*											1	Prefers single loader
		Co. I, 10th Cav	*H.*, C.-R												No preference; about equal to service as to shooting qualities.
		Co. M, 10th Cav	*Lee*, H., C.-R			1				1				1	
		Co. A, 1st Inf	*C.-R.*, H., Lee			1								1	Lee next, C.-R. third
		Co. B, 1st Inf	*Lee*, C.-R	1						1				1	
		Co. F, 1st Inf	*H*							1			1		No comparison; likes H. very much.
		Co. I, 1st Inf	do							1			1	1	do
		Co. K, 1st Inf	*C.-R.*, H												No choice.
			Total	1	0	2	0	0	0	4	0	0	2	5	
	The Columbia.	Co. B, 2d Cav	*Lee*, C.-R., H	1										1	
		Co. E, 2d Cav	*H.*, Lee, C.-R	1											No comparison with service.
		Co. I, 2d Cav	*C.-R*												No comparisons; unfit for cavalry service.

*H.—Hotchkiss; C.-R.—Chaffee-Reece; arm (or arms) issued to each company, &c., is in italic.

Objections, &c.

H.—Sights not properly graduated; front sight too coarse.

Lee.—Reloaded ammunition works badly; if magazine lost, reduced to single loader; slot in front of trigger-guard an avenue for dust. C.-R.—Demands too much force to operate bolt. H.—Cartridges impinging in magazine; danger of explosion.

C. R. and H.—Cartridges jam in chamber in rapid firing.
All.—Full cock after loading. H.—Reloaded ammunition works badly; piece likely to be discharged: (1) if bolt closed suddenly in loading; (2) at "order arms" if cut-off forgotten; sights poor; cartridges in magazine likely to explode; knob of bolt should be bent down. Lee.—Too many magazines on belt.
C.-R.—Too great friction in loading. H.—Large frictional surface; heavy in breech block.
C.-R.—Mechanism complicated and works very hard, especially when fouled; dirt gets in easily; reloaded ammunition works badly; trigger "creep" excessive; danger of premature explosion in loading magazine.
Lee.—Magazine belt awkward and easily collecting dust in field service. H. and C.-R.—Danger of explosion in magazine; stocks weakened by magazine insertion. All.—Complicated mechanism easily clogged.
C.-R.—Excessive trigger pull; reloaded ammunition works badly. C.-R. and H.—Weak stock; dangerous magazine system. All.—Full cock after loading; premature explosion liable from bolt slipping when half cocking; breech mechanism complicated and easily fouled.
H. and C.-R.—Breech mechanism complicated and easily clogged; dangerous magazine; stock weakened by magazine insertion.

C.-R.—Can use only regulation rifle ammunition; mechanism complicated and liable to clog; fails to throw cartridge into chamber; reloaded ammunition works badly; empty shells not easily saved.
H.—Breech mechanism insufficiently protected from dust, &c. H. and C.-R. Great care necessary in adjusting cut-off, to prevent premature explosion.

Lee.—Breech mechanism complicated, and not well protected; magazine may easily rust into frame, get bent, &c.
C.-R.—Breech mechanism complicated and easily disarranged, fouled, &c.; fails to throw up cartridge into chamber; attention to management of guns spoils accuracy of firing.
Lee and C.-R.—Breech mechanism complicated, exposed to dust, and works hard; fails sometimes to eject shell. Lee.—Magazine belt clumsy, &c.; not suitable in "manual." C.-R.—Cartridges sometimes jam at the entrance to magazine.
H.—V rear sight objectionable.

H.—Breech mechanism easily fouled; knob unsightly and easily broken; trigger "creeps;" short barrel; forward cartridge in magazine often prevents piece remaining cocked; awkward to load in marching; increased twist in rifling causes heating and "leading."
C.-R. and H.—Breech mechanism too exposed, and liable to rust, foul, &c.; great care to adjust cut-off, to prevent premature discharge.

All.—Bolt system unfitted for cavalry service; too easily fouled with dust, &c. C.-R.—Breech mechanism works very hard; pin fails to discharge cartridges at times. H.—Magazine spring fouls, and will not throw up cartridges.
All.—Not well sighted; complicated mechanism liable to accident in field service. H.—Not fired well in "Texas grip"; magazine spring weak and often ineffective; stock weak. Lee.—Magazine fragile and easily injured in field service. H. and C. R.—Magazine action not smooth.
C.-R.—No way to carry as cavalry gun; mechanism complicated and easily fouled in field service; magazine mechanism works hard.

Division.	Department.	Issued to— Regiment, company, &c.	Arm on trial and reported on.	Magazine guns compared with each other. Preference. Lee.	Chaffee-Reese.	Hotchkiss.	Magazine guns compared with service rifle. Preference. As single loaders. Lee.	Chaffee-Reese.	Hotchkiss.	Service.	For all uses. Lee.	Chaffee-Reese.	Hotchkiss.	Service.	Remarks.
The Pacific—continued.	The Columbia—continued.	Co. A, 2d Inf	*Lee*				1			1					
		Co. E, 2d Inf	do												No definite comparisons.
		Co. F, 2d Inf	*H*						1	1				1	
		Co. G, 2d Inf	*C. R*												No proper test made.
		Co. H, 2d Inf	*H*												No comparisons; likes H. very much.
		Co. K, 2d Inf	*C.-R*											1	
		Co. A, 14th Inf	*Lee*, C.-R., H	1											No comparison with service.
		Co. D, 14th Inf	*Lee*												No comparison; Lee best gun he has seen.
		Co. E, 14th Inf	*C.-R.*, Lee, H	1	1										No comparison with service.
		Co. F, 14th Inf	do	1											H. second, C.-R. third; no comparison with service.
		Co. G, 14th Inf	*H*									1			No comparison with magazine guns; decided preference over service.
		Co. H, 14th Inf	*Lee*, C.-R., H	1											No comparison with service.
		Co. I, 14th Inf	*H*												Nothing definite; likes H.; no comparisons.
		Co. K, 14th Inf	do												do
			Total	6	1	0	1	0	1	2	0	1	0	3	
	Dakota.	Co. B, 3d Inf	*C.-R.*, *H.*, *Lee*	1											No comparison with service; all have fatal defects.
		Co. D, 3d Inf	*H.*, C.-R., Lee			1								1	Service best in the world.
		Co. I, 3d Inf	*Lee*, C.-R., H	1						1				1	
		Co. B, 5th Inf	*C.-R.*, H., Lee		1									1	
		Co. C, 5th Inf	*H.*, Lee, C.-R			1									All equal as single loaders; no comparison with service.
		Co. G, 5th Inf	*Lee*, H., C. R												No comparison with service; Lee better single loader, and in breech mechanism, not in magazine system.
		Co. D, 11th Inf	*Lee*												No comparisons; not superior to service; likes Lee as magazine gun.
		Co. E, 11th Inf	*H.*, Lee, C.-R	1											No decisive comparison with service; excellent report.
		Co. K, 11th Inf	*C.-R.*, Lee, H												No decisive comparison; no advantage over service.
		Co. A, 15th Inf	*C.-R.*, Lee, H			1								1	

ISSUED FOR TRIAL, ETC.—Continued.

Objections, &c.

Lee.—Reloaded ammunition used with difficulty; mechanism easily clogged by dust, &c.; magazines not easily transferred under fire; belt carries less ammunition and more weight than service.
Lee.—Mechanism complicated and hard to take care of; unsuited to "manual;" no way to tell if cartridges remain in magazine.
H.—Difficulty with reloaded ammunition; breech-bolt in awkward position; unsuitable for manual.

H.—V-shaped rear sight unsatisfactory; mechanism probably easily fouled in field service.

C.-R.—Trigger pull excessive and especially objectionable in lying or sitting positions; breech mechanism hard to work; misfires frequent, owing to weakness of spring; magazine action easily obstructed, and feed unreliable; unsuited to "manual."
Lee.—Breech mechanism too exposed; easily rusts and fouls; recoil greater than service; sights poorly graduated; cartridge belt clumsy.

C.-R.—Excessive trigger pull; piece too heavy.

C.-R.—Excessive trigger pull; breech mechanism works hard, easily liable to rust and fouling; cut-off thumb-piece too easily moved by accident; unsuited generally for field service. H.—Badly sighted.
H.—Sights coarse; V-shaped rear sight objectionable; gun badly sighted.

Lee.—Difficulty with reloaded ammunition.

H.—Reloaded ammunition used with difficulty; mainspring weak; ill-suited to "manual;" sights badly graduated.
H.—Reloaded ammunition works badly; mainspring weak; misfires occasionally; V-shaped rear sight objectionable; sights poorly graduated.

C.-R.—Manner of connecting magazine bad; dirt enters groove and fouls mechanism; breech mechanism complicated. H.—Dangerous magazine. Lee.—When magazine detached dirt enters easily and fouls; belt arrangement clumsy. Lee and C.-R.—Method of cocking piece requires too great force.
H.—Short barrel; sighted poorly; bullets nicked when firing rapidly from magazine, which affects accuracy; extractor spoils shell for reloading.
Lee.—Belt objectionable.
C.-R.—Excessive trigger-pull; reloaded ammunition works badly; breech mechanism easily fouled and works very hard; unsuited to manual. H.—Dangerous magazine. Lee.—Magazine readily lost and injured in service.
H.—Mechanism easily deranged and hard to keep clean; snow, &c., obstructs it completely; magazine dangerous from position of cartridges; unsuited to manual; magazine spring likely to kink and prevent use; bullets flattened.
Lee.—Difficulty with reloading ammunition; magazine liable to loss, &c., in action; detachable system bad; belts inconvenient; breech mechanism works hard, and not easily kept clean in field service; liability to premature discharge.

Lee.—Magazine spring fails to feed up; belt objectionable.

H.—Unsafe magazine; magazine spring kinks and refuses to work. C.-R.—Excessive trigger-pull; breech mechanism complicated; magazine system easily deranged.

C.-R.—Magazine cut-off readily displaced in operating breech mechanism, whereby action of piece choked. H.—Danger of explosion in magazine. Lee.—Mechanism too complicated and liable to injury for field service.
C.-R.—Unsuited to manual; reloaded ammunition works badly; magazine cut-off system defective; extractor cuts shell; trigger-pull excessive; barrel too short; stock too thick; breech-block too bright; all these affect accuracy of fire; main-spring weak and fails to discharge piece.

SUMMARY OF REPORTS ON MAGAZINE-GU

Division.	Department.	Issued to— Regiment, company, &c.	Arm on trial and reported on.	Magazine guns compared with each other. Preference. Lee.	Chaffee-Reece.	Hotchkiss.	Magazine guns compared with service rifle. Preference. As single loader. Lee.	Chaffee-Reece.	Hotchkiss.	Service.	For all uses. Lee.	Chaffee-Reece.	Hotchkiss.	Service.	Remarks.
The Pacific—continued.	Dakota—continued.	Co. C, 15th Inf	*Lee*												No comparisons; Lee not suitable in all respects for service.
		Co. H, 15th Inf	*H.*, Lee, C.-R.		1	1									No comparison with service.
		Co. B, 25th Inf	*H.*, Lee, C.-R.			1									do
		Co. C, 25th Inf	*Lee*, C.-R., H.												No definite comparison; prefers magazine system of C.-R.
		Co. F, 25th Inf	*C.-R.*, Lee, H.		1										No comparison with service.
		Total		3	3	5				1				4	
	The Platte.	Co. A, 6th Inf	*Lee*, *C.-R.*, *H*			1								1	Neither can replace service for field use.
		Co. B, 6th Inf	*Lee*, *C.-R.*, *H.*			1									No comparison with service.
		Co. C, 6th Inf	*Lee*, *C.-R.*, *H.*	1						1				1	
		Co. D, 6th Inf	*Lee*, *C.-R.*, *H.*			1								1	C.-R. next
		Co. E, 6th Inf	*Lee*, *C.-R.*, *H.*			1								1	Lee second, C.-R. third.
		Co. F, 6th Inf	*Lee*, *C.-R.*, *H.*	1											No comparison with service.
		Co. G, 6th Inf	*Lee*, *C.-R.*, *H.*			1									do
		Co. H, 6th Inf	*Lee*, *C.-R.*, *H.*			1									do
		Co. I, 6th Inf	*Lee*, *C.-R.*, *H.*	1		1				1					
		Co. K, 6th Inf	*Lee*, *C.-R.*, *H.*			1									No comparison with service; neither magazine gun at present used to advantage by soldiers.
		Co. A, 7th Inf	*Lee*, C.-R., H.	1										1	
		Co. D, 7th Inf	*H*							1					No comparison with magazine guns.
		Co. K, 7th Inf	*C.-R*												No comparisons; an unsafe arm.
		Co. A, 9th Inf	*Lee*, *C.*-R., *H.*	1											No comparison with service.
		Co. D, 9th Inf	*Lee*, *H.*, *C.-R.*		1					1					Lee second, C.-R. third.
		Co. E, 9th Inf	*Lee*, *H.*, *C.-R*	1						1					H. and C.-R. about equal
		Co. F, 9th Inf	*Lee*, *H.*, *C.-R.*		1									1	Lee second
		Co. H, 9th Inf	*Lee*, *H.*, *C.-R.*		1					1				1	Lee second, H. third.
		Co. I, 9th Inf	*Lee*, *C.-R.*, *H.*		1									1	
		Co. K, 21st Inf	*Lee*, *C.-R.*, *H.*	1										1	Opposed to a magazine gun.
		Total		7	4	8				6				9	

ISSUED FOR TRIAL, ETC.—Continued.

Objections, &c.

Lee.—Full cock after loading; stud on hammer quickly worn down; cannot use reloaded ammunition; magazine belt unsuited to use in action; inconvenient in manual; force required to operate bolt lames hand, and tends to derange fire.

H.—Short barrel; affects accuracy of fire, especially in recumbent positions; dangerous magazine; sites poor. C.-R. and H.—Firing-pin spring weak and fails to discharge. Lee.—Detached magazine impracticable in field service; belt clumsy. Lee and C.-R.—Breech mechanism stiff.

H.—Can't use reloaded ammunition; bullet abraided in entering chamber; short barrel impairs accuracy of fire. Lee.—Magazine liable to injury; magazine system impracticable for field service. C.-R.—Breech mechanism takes too much muscle to operate.

Lee.—Reloaded ammunition used with great trouble; locking device unsafe.

C.-R.—Reloaded ammunition used with difficulty; trigger-pull excessive; sights not properly placed; breech-locking system defective. H.—Danger of explosion in magazine. Lee.—Detachable magazine and belt system objectionable.

C.-R.—Breeh mechanism works hard.

All.—Complicated mechanism; reloaded ammunition works badly. C.-R. and H.—Dangerous hammer system; men not likely to use properly magazine system, cutting off and throwing on, at times of excitement. C.-R.—Creep of trigger. H.—Dangerous magazine system; cartridges in contact. Lee.—Cartridges often block and fail to feed; hammer full cock at loading; firing-pin liable to break magazine-belt awkward and heavy; trigger-pull not easily regulated.

C.-R.—Complicated mechanism.

C.-R.—Fails often to throw cartridge into chamber; mechanism works hard.

C.-R.—Complicated and difficult mechanism; lost motion in trigger-pull; slide-bar in magazine gets unhooked; Lee.—Magazine liable to dropping and injury; belt cumbersome.

H.—Danger of explosion in magazine; Lee and C.-R.—No means to lock hammer at full cock. Lee.—Magazine often removed with difficulty. C.-R.—Complicated mechanism.

C.-R.—Breech mechanism complicated and works hard, liable to fouling and injury. Lee.—Magazine likely to be lost in action; belt cumbersome. H.—Bullets "stripped."

All.—Reloaded ammunition works badly. C.-R. and H.—Bullets become flattened in magazine and affect accuracy of fire. C.-R.—Breech mechanism works heavily; cartridges jam. Lee.—Magazine not easily adjusted, and bolt awkward.

H.—Danger in cartridges in contact in magazine. Lee.—Belt heavy and awkward.

H.—Reloaded ammunition works badly; cartridge thrown into chamber so violently as to flatten head of bullet and impair accuracy of fire.

C.-R.—Sights inaccurate; breech mechanism complicated; magazine only attachable when chamber closed by button; if latter moved when chamber open, piece rendered useless as magazine gun; can be discharged sometimes at half-cock.

Lee.—Detachable magazine. H.—Cartridges jam; accidental explosion possible. C.-R.—Main-spring weak; stock too large and heavy: trigger-pull excessive; reloaded cartridges fail to explode often.

H.—Cartridges so close in magazine that bullets chipped. Lee.—Numerous lands and grooves hard to keep clean.

H.—Cartridges liable to explode in magazine. Lee.—Magazine clumsy and impracticable for field use.

H.—Dangerous magazine system; difficult to remove firing-pin; "leads." Lee.—Magazine interferes with left hand in firing; "leads;" breech mechanism faulty; key-sleeve works hard; firing-pin often fails to reach primer; firing-pin hard to replace. C.-R.—Breech mechanism faulty; trigger "creeps"; lifting spring weak; rear sight not properly placed.

Lee.—Magazine too heavy, and method of carrying it clumsy. C.-R.—Breech mechanism complicated. H.—Danger of explosion in magazine, and of deformation of cartridges.

SUMMARY OF REPORTS ON MAGAZINE-GUNS

Issued to—			Arm on trial and reported on.	Magazine guns compared with each other.			Magazine guns compared with service rifle.								Remarks.
				Preference.			Preference.								
							As single loader.				For all uses.				
Division.	Department.	Regiment, company, &c.		Lee.	Chaffee-Reece.	Hotchkiss.	Lee.	Chaffee-Reece.	Hotchkiss.	Service.	Lee.	Chaffee-Reece.	Hotchkiss.	Service.	
The Missouri.	The Missouri.	Co. H, 5th Cav	*Lee, H., C.-R.*	1										1	H. second, C.-R. third.
		Co. H, 1st Inf	*H.*, Lee, C.-R.	1											No comparison with service.
		Co. A, 4th Inf	*Lee*				1								No comparison with magazine guns.
		Band, 10th Inf	*Lee*, C.-R., H.	1										1	No comparison with service.
		Co. A, 10th Inf	*Lee, H., C.-R.*			1									No comparison with service; a soldier in four hours fight would fire from service gun more ammunition than he could carry.
		Co. B, 10th Inf	*H*							1					No comparison with magazine guns.
		Co. C, 10th Inf	*C.-R.*, Lee, H.	1										1	
		Co. D, 10th Inf	*H., Lee, C.-R.*											1	No comparison with magazine guns.
		Co. F, 10th Inf	*H*											1	No comparison with magazine guns.
		Co. G, 10th Inf	*Lee, C.-R., H.*											1	No comparison with magazine guns; all greatly inferior to service.
		Co. H, 10th Inf	*Lee, C.-R., H.*			1									No comparison with service.
		Co. I, 10th Inf	*Lee*, C.-R., H.	1											No comparison with service.
		Co. G, 11th Inf	*C.-R.*, H., Lee	1							1		1		C.-R. second, H. third.
		Co. C, 13th Inf	*Lee, C.-R., H.*											1	No comparison of magazine guns.
		Co. E, 13th Inf	*Lee, C.-R., H.*	1											No comparison with service; wouldn't recommend Lee for general use.
		Co. H, 13th Inf	*Lee*											1	No comparison of magazine guns; Lee has no advantage over service.
		Co. I, 13th Inf	*C.-R.*, Lee, H.	1										1	C.-R. second, H. third.
		Co. K, 13th Inf	*Lee, C.-R., H.*	1											No comparison with service; fine repeat— C.-R. disabled at start.
		Co. H, 18th Inf	*Lee*												Nothing definite.
		Co. I, 18th Inf	*C.-R., Lee, H.*											1	No comparison of magazine guns.
		Co. I, 20th Inf	*Lee*								1				No comparison of magazine guns.

ISSUED FOR TRIAL, ETC.—Continued.

Objections, &c.

All.—Unfit for field service; breech exposed; necessity to carry oil; unhandy in "manual"; breech mechanism complicated.

Lee.—Bullet strikes edge of chamber in entering, and accuracy of fire impaired thereby; reloaded ammunition works badly; magazine easily lost in action; belt cumbersome and ill designed; springs stick out, &c.

Lee.—Sights too coarse; reloaded ammunition works badly; magazine easily lost in action.

H.—Manner of loading magazine. C.-R.—mechanism too complicated. Lee.—Belt and magazines weigh too much; magazines liable to injury in active service.

H.—Sights coarse; reloaded ammunition works badly.

C.-R.—Breech mechanism complicated; works hard when much used; trigger "creeps;" danger of explosion in magazine; reloaded ammunition works badly. Lee.—Heavy and clumsy magazine belt.

All.—Reloaded ammunition works badly; sand test not borne; knob in way at "manual." Lee.—Sights poorly adjusted.

H.—Reloaded ammunition works badly; cartridges jam and prevent action of bolt; danger of explosion in magazine.

All.—Breech mechanism liable to fouling, injury, jamming, rust, &c.; knobs an obstruction in "manual." in absence of hammer nothing to show if piece is cocked; full cock after loading; difference in full and half-cock hardly perceptible; half-cock from full-cock requires great force, &c. H. and C.-R.—Danger of explosion in magazine.

All.—Difficulty with reloaded ammunition. Lee.—When loaded full to half-cock at risk of slipping and exploding cartridges; rear sight ill adjusted.

H.—Danger of explosion in magazine. C.-R.—Magazine liable to choke. H. and C.-R.—Bolts awkward to operate.

C.-R.—Too heavy; defective mechanism for operating magazine, and for attaching magazine; excessive trigger-pull; if less than full number of cartridges in magazine extra motion with bolt necessary to bring up first one; inclosing breech-bolt must carry forward whole column of cartridges. H.—Danger of explosion in magazine. C.-R. and H.—Nothing to remind that last cartridge in magazine has been used. Lee.—Belt unwieldy; no cut-off to magazine.

H.—Mechanism complicated; excessive trigger-pull; "creeping" trigger; shorter point-blank and total range, and shorter dangerous space at all ranges. C.-R.—Trigger-pull abominable; trigger "creeps."

Lee.—Must use both hands to bring hammer to safety notch after loading; hammer liable to slip and discharge piece; breech mechanism works hard when fouled; in "Texas grip" hammer in recoil strikes hand.

C.-R.—Excessive trigger-pull; firing-pin often fails to discharge; mechanism works very hard; reloaded ammunition works badly; cartridges jam at magazine entrance; short barrel affects accuracy. H.—Magazine complicated. C.-R. and H.—Rifling-twist to right.

H.—Breech mechanism clogs and works hard; clogged by dirty cartridges; in rapid firing excessive heat generated, and great force necessary to open breech. Lee.—Belt arrangement interferes with rapid fire in field.

Lee.—Magazine springs could be improved.

SUMMARY OF REPORTS ON MAGAZINE-GUN

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The Missouri—continued.	The Missouri—continued.	Co. A, 22d Inf	*Lee*, *H.*, *C.-R.*	1											No comparison with service; which is free from defects common to all.
		Co. B, 22d Inf	*C.-R.*												No comparison; not superior to service as single loader.
		Co. C, 22d Inf	*Lee*, *C.-R.*, *H.*	1						1					Fears it would not do for field service.
		Co. D, 22d Inf	*H.*, Lee, C.-R.			1									No comparison with service.
		Co. G, 22d Inf	*C.-R.*, Lee, H.	1											H. second; no comparison with service.
		Co. H, 22d Inf	*H.*, Lee, C.-R.	1										1	
		Co. K, 22d Inf	*Lee*, C. R. H.	1											No comparison with service.
		Co. C, 24th Inf	*H.*, Lee, C.-R.	1											No comparison with service.
		Co. D, 24th Inf	*H.*, Lee, C.-R.	1							1				
		Co. E, 24th Inf	*Lee*, C.-R., H.	1							1			1	
		Co. G, 24th Inf	*C.-R.*, Lee, H.	1							1				
		Co. H, 24th Inf	*Lee*, C.-R., H.	1											No comparison with service.
		Co. I, 24th Inf	*C.-R.*, Lee, H.	1											No comparison with service; H. and C.-R. equal.
		Total		20	0	3	1	0	0	2	5	0	1	11	
	Texas.	Co. A, 16th Inf	*C.-R.*											1	No definite comparison.
		Co. C, 16th Inf	*H.*, Lee, C.-R.							1					Magazines of all defective; no comparison.
		Co. D, 16th Inf	*Lee*, C.-R.	1											No comparison with service.
		Co. E, 16th Inf	*C.-R.*, Lee	1										1	
		Co. H, 16th Inf	*Lee*, C.-R., H	1										1	
		Co. I, 16th Inf	*H*											1	No comparison of magazine guns.
		Co. K, 16th Inf	*Lee*											1	do.
		Co. A, 19th Inf	*C.-R.*, H., Lee			1									No comparison with service.
		Co. B, 19th Inf	*C.-R.*, H., Lee		1										Lee second, H. third; no comparison with service.

ISSUED FOR TRIAL, ETC.—Continued.

Objections, &c.

All.—Reloaded ammunition works badly; swollen shells extracted with difficulty. C.-R. and H.—Mechanism complicated and liable to injury.

C.-R.—Trigger-pull excessive; magazine mechanism fails to work at times; empty shells block action of mechanism occasionally; magazine becomes disconnected in firing.

All.—Reloaded ammunition works with difficulty. H.—Magazine probably loaded with difficulty in cold weather. C.-R.—Breech mechanism complicated. Lee.—Dust likely to clog breech mechanism in field service; cartridges sometimes exploded in closing breech.

All.—Reloaded ammunition works badly. C.-R.—Breech mechanism complicated and hard to operate.

C.-R.-Breech mechanism works hard. When desired to use as single loader—magazine filled—cartridges liable to work up and prevent operation of breech mechanism completely; cartridges often jam; cut-off gets out of gear and disables piece; pin of cut-off bar slips from slot; magazine fails to throw up cartridge; heads of bullets bruised.

H.—Cartridges fail to explode; sights ill adjusted; mechanism intricate; hard to work, to clean, and to keep clean; reloaded ammunition works with difficulty.

Lee.—Reloaded ammunition works badly; unsuitable for "manual." H.—Shells jam in rapid firing; spring in magazine too weak to throw up last one or two cartridges when muzzle elevated. C.-R.—Bolt works stiffly; trigger-pull badly regulated; used as single loader, magazine charged, often jams; as magazine-gun, cartridges not always thrown up.

H.—Magazine inconvenient to load. C.-R.—Cartridges in magazine liable to be exploded.

H.—V-shaped rear sight; barrel too short; danger of explosion in magazine; cartridges clog in feeding.

C.-R. and H.—Magazine in butt stock an element of danger.

C.-R.—Mechanism complicated; loading magazine difficult and dangerous.

Lee.—Trigger-pull uncertain.

Lee.—If bolt handle not wholly turned to right hammer strikes projection and fails to reach cartridge; bolt mechanism clumsy. C.-R.—Complicated mechanism; magazine difficult to load in action; trigger-pull uncertain and disagreeable. H.—Danger of explosion in magazine.

C.-R.—Too great trigger-pull; reloaded ammunition works hard; breech mechanism complicated and hard to operate; in action difficult to know if magazine is on or off; cut-off button is worked with difficulty.

H.—Short barrel; sights not properly placed; cannot lock without hammer at full-cock; magazine defective.

C.-R.—Disabled by dusting; too many parts likely to collect and be disabled by dust, &c. Lee.—Cannot use as single-loader when magazine attached; belt system bad; magazine liable to loss in action; belt magazine-holders deface stock in manual.

C.R.—Breech mechanism works very hard.

Lee.—Recoil severe; extractor unreliable; breech mechanism choked by inability to release bolt after firing; fails sometimes to explode cartridges; magazine easily disconnected by accident; dirt falls from chamber to bottom of magazine; collects and obstructs; bolt-handle in recoil strikes forefinger; magazine belt clumsy; cannot be used firing on back, when sling takes up recoil.

H.—Ramrod poorly secured; rear sight bad; rear sling swivel; thickness and drop of stock impair good aim; arm of breech mechanism in way in manual; ejector tears through rim of shell.

Lee.—Reloaded ammunition used with difficulty; breech mechanism works very hard; cartridge belt unwieldy; bolt an obstruction in manual; bolt and extractor sometimes fail to work; extractor cuts head of shell; in locking piece hammer becomes immovable.

C.-R.—Trigger-pull excessive; cut-off button easily broken; moves too readily, and may alter from magazine gun to single-loader, and *vice versa*, without knowledge of man; if moved when breech open mechanism is disabled; breech mechanism complicated, delicate, and misleading; entrance to magazine in butt-plate objectionable. H.—Danger of explosion in magazine. Lee.—Detachable magazine liable to loss and injury.

C.-R.—Excessive trigger-pull. H.—Danger of explosion in magazine.

SUMMARY OF REPORTS ON MAGAZINE-GUNS

Division.	Department.	Issued to— Regiment, company, &c.	Arm on trial and reported on.	Magazine guns compared with each other. Preference. Lee.	Chaffee-Reece.	Hotchkiss.	Magazine guns compared with service rifle. Preference. As single loader. Lee.	Chaffee-Reece.	Hotchkiss.	Service.	For all uses. Lee.	Chaffee-Reece.	Hotchkiss.	Service.	Remarks.
The Missouri—continued.	Texas—continued.	Co. C, 19th Inf.	*C.-R.*, Lee, H.	....	1	....	..	..	..	..	..	..	..	..	No comparison with service; prefers 3-groove rifling to 5.
		Co. D, 19th Inf.	*H.*, Lee, C. R.	....	....	....	..	..	..	..	..	..	..	1	Three magazine guns about equal.
		Co. E, 19th Inf.	*H*	....	....	....	..	..	..	1	..	..	..	..	No comparison with magazine guns.
		Co. F, 19th Inf.	*Lee*, C.-R., H.	....	1	....	..	..	..	..	..	..	..	1	....
		Co. H, 19th Inf.	*H.*, Lee, C.-R.	....	....	1	..	..	..	..	..	..	..	..	No comparison with service; does not consider Lee in class of magazine guns.
		Co. I, 19th Inf.	*Lee*, H., C.-R.	...	....	1	..	..	..	..	..	..	..	..	No comparison with service; prefers bolt system as single-loader to service.
		Co. K, 19th Inf.	*C.-R*	....	....	....	..	..	..	..	..	1	..	..	No comparison with magazine guns.
		Total		3	3	3	..	..	..	2	..	1	..	7	
The Atlantic.	The East.	Co. G, 1st Art.	*Lee*	....	...	....	..	..	..	..	..	..	..	..	No comparisons
		Co. B, 2d Art.	*Lee*	....	....	....	..	..	..	..	1	..	..	..	No comparison with magazine guns.
		Co. D, 2d Art.	*H.*	....	....	....	..	..	..	..	..	..	..	..	No comparisons; useful only for escort duty with intelligent men.
		Co. H, 2d Art.	*C.-R.*, H., Lee	1	....	....	..	..	..	..	..	..	..	..	No comparison with service.
		Co. I, 2d Art.	*C.-R.*, H., Lee	....	1	....	..	..	..	..	..	..	..	..	......do ......
		Co. K, 2d Art.	*C.-R.*, H., Lee	....	....	1	..	..	..	..	..	..	..	..	No comparison with service; C.-R. second; Lee third; all good single-loaders
		Co. L, 2d Art.	*Lee*, H., C.-R.	1	....	....	..	..	..	..	..	..	..	..	No comparison with service; H. second, C.-R. third.
		Co. M, 2d Art.	*H.*	....	....	....	..	..	..	..	..	..	..	..	Nothing definite.
		Co. B, 3d Art.	*C.-R.*, H., Lee	....	1	....	..	..	..	..	..	..	..	..	No comparison with service.
		Co. E, 3d Art.	*H.*, C.-R., Lee	....	....	1	..	..	..	..	..	..	..	..	......do ......
		Co. K, 3d Art.	*Lee*, C.-R., H	1	....	....	1	..	..	1	1	..	..	1	....
		Co. D, 4th Art.	*H.*, Lee, C.-R.	1	....	....	..	..	..	..	..	..	..	..	H. second; no comparison with service.
		Co. E, 4th Art.	*Lee*, C.-R., H.	1	....	....	..	..	..	..	..	..	..	..	H. second; no comparison with service (drawing of suggested belt).
		Co. I, 4th Art.	*H.*, Lee, C.-R.	....	....	1	..	..	..	..	..	..	1	..	....

ISSUED FOR TRIAL, ETC.—Continued.

Objections, &c.

H.—Must pull trigger and snap gun to throw up cartridge from magazine, followed by bolt movements that, incorrectly made, may cause premature discharge; magazine dangerous, liable to explosion, hard to fill. Lee.—Belt cumbrous; magazine liable to be lost in action. C.-R.—Excessive trigger-pull.
H.—Magazine dangerous.

H.—Poor sights; trigger-pull heavy; magazine cannot be loaded or unloaded without cocking piece; dangerous magazine.
Lee.—Belt arrangement restricts amount of ammunition carried; difficult to manage belt and magazine in action; no cutting off magazine; reloaded ammunition used with difficulty; as single-loader, large opening in bottom of receiver faulty. H.—Magazine dangerous. C.-R.—Action of cut-off confusing to ordinary soldier.
C.-R.—Magazine system objectionable; requires gun to be held muzzle downward in loading.

Lee.—Reloaded ammunition works badly; full-cock when loaded. C.-R.—Cut-off stud clumsy, ineffective, and, wrongly used, completely disables piece. H.—Dangerous magazine.

C.-R. Excessive trigger-pull.

Lee.—Belts do not admit bayonet-scabbard attachment; unsafe to bring to half-cock.
Lee.—Reloaded ammunition used with difficulty; unsuited to manual; belt clumsy; bayonet-scabbard and sergeant's pistol-holster unprovided for.
H.—Inaccurate sights; V-shaped rear sight objectionable; reloaded ammunition works badly; nothing to indicate when magazine is empty.

C.-R.—Sights improperly placed; breech mechanism easily disordered; cut-off fails to work; magazine does not feed well; cartridges jam, &c.; breech mechanism complicated, and trigger-pull excessive; reloaded ammunition used with difficulty; unsuited for manual.
C.-R.—Excessive trigger-pull; badly sighted; magazine mechanism works hard; reloaded ammunition difficult to use in magazine; bright surface in front of eyes affects aim. H.—Dangerous magazine. Lee.—Detached magazine an objection.
C.-R.—Excessive trigger-pull; too thick stock; badly sighted; breech mechanism complicated and easily fouled; discharges at half-cock; magazine cut-off button easily broken; mechanism of magazine not always works; firing-pin fails to explode cartridges; reloaded ammunition used with difficulty. H.—Dangerous magazine. Lee.—Magazine liable to loss; belt arrangement cumbersome.
Lee.—Full-cock after loading; cannot use as single-loader with magazine attached.

H.—Unsuited to manual.
C.-R.—Difficulty with reloaded ammunition; cut-off too easily displaced; breech mechanism easily fouled and obstructed.
H.—V rear sight objectionable; reloaded ammunition used with difficulty in magazine. C.-R.—Latch of loading-hole likely to choke with dirt. Lee.—Liability of magazine to injury.
Lee.—Magazine-spring weak; belt system inconvenient; somewhat unsuited for manual.
H.—V rear sight objectionable; sights defective; safety-lock easily overlooked; magazine dangerous; reloaded ammunition clogs magazine action; ill suited to manual.
Lee.—Danger in coming to half-cock; belt arrangement clumsy; no cut-off to magazine; unsuited to manual. C.-R.—Great trigger-pull; safety-notch chipped out frequently; cut-off too readily moved; dangerous; reloaded ammunition used with difficulty; unsuitable for manual. H.—Rear sight bad; cut-off too easily moved; reloaded ammunition used with difficulty.
H.—Rear sight too far forward; badly sighted; firing-pin spring weak; when 500-grain cartridges used bolt chafes groove in forward cartridge of magazine; magazine sometimes feeds up when cut off; piece discharged at order arms if cocked and not locked. C.-R.—Easily affected by sand, &c.; magazine hard to load; feed mechanism complicated and uncertain; easily fouled; bolt works hard against spring. Lee.—Bolt works hard against spring; dangerous method of locking bolt; detached magazine objectionable; cannot use as single-loader with magazine attached; belt and magazine easily damaged.

SUMMARY OF REPORTS ON MAGAZINE-GUNS

Division.	Department.	Issued to—Regiment, company, &c.	Arm on trial, and reported on.	Magazine guns compared with each other. Preference. Lee.	Chaffee-Reece.	Hotchkiss.	Magazine guns compared with service rifle. Preference. As single loader. Lee.	Chaffee-Reece.	Hotchkiss.	Service.	For all uses. Lee.	Chaffee-Reece.	Hotchkiss.	Service.	Remarks.
The Atlantic—continued.	The East—continued.	Co. L, 5th Art	*C.-R.*, Lee, H.	1											No comparison with service; Lee decidedly superior.
		Co. I, 5th Art	*C.-R.*												No comparison
		Co. L, 5th Art	*H.*, Lee, C.-R.	1											No comparison with service.
		Co. M, 5th Art	*Lee*, C.-R., H.	1			1				1				
		Co. A, 12th Inf	*H.*												No comparisons
		Co. B, 12th Inf	*C.-R.*												do
		Co. D, 12th Inf	*Lee*								1				No comparison with magazine guns; hopes it will be adopted for the Army.
		Co. F, 12th Inf	*Lee*, C.-R., H.	1											No comparison with service.
		Co. G, 12th Inf	*C. R.*												No comparisons; difficult to express opinion.
		Co. I, 12th Inf	*H.*												No comparisons
		Co. F, 23d Inf	*Lee*, C.-R., H.	1										1	
		Co. G, 23d Inf	*C.-R.*, H., Lee		1							1		1	
		Co. I, 23d Inf	*H.*											1	No comparison with magazine guns; hammerless gun not safe in hands of troops.
		Total		10	3	3	2	0	0	1	4	1	1	4	
Grand total				55	14	26	5	0	1	21	10	3	4	46	

ISSUED FOR TRIAL, ETC.—Continued.

Objections, &c.

C.-R.—Excessive trigger-pull; breech mechanism complicated; works hard and easily disabled; reloaded ammunition used with difficulty; unsuited to manual; stock too large and weak; would not stand field service. H.—Dangerous magazine.

C.-R.—Reloaded ammunition used with difficulty; breech mechanism works hard; trigger-pull excessive; danger of explosion in magazine; magazine liable to be thrown off by accident in closing bolt, &c.

C.-R.—Excessive trigger-pull. C.-R. and H.—Bullet strikes end of chamber in passing from receiver. H.—Dangerous magazine; magazine does not always feed; reloaded ammunition used with difficulty; firing-pin fails to discharge; springs appear to lose strength; V rear sight objectionable; recoil excessive,

Lee—Reloaded ammunition works poorly; ramrod too short.

H.—V rear sight objectionable; unsuited to manual.

C.-R.—Full cock after loading; trigger-pull excessive; reloaded ammunition can't be used.

Lee—Full cock at loading; unadapted to manual.

Lee—Full cock after loading; danger in going from full cock to half cock; unsuited to manual.

C.-R.—Full cock at loading; fails to discharge cartridges; breech mechanism too little protected for field use.

H.—Coarse sights; short barrel; dangerous magazine; reloaded ammunition works poorly; unsuited to manual; breech mechanism complicated and liable to damage; magazine cut-off too small; hard to handle, &c.

All—Full cock after loading; unsuited to manual; hard to pull off in lying position. H. & C.-R.—Difficulty with reloaded ammunition. Lee—Parts soon worn down and mechanism obstructed; bolt handle strikes forefinger after discharge. H. & C.-R.—Failure to explode cartridges. H.—Cartridges strike edge of chamber and impair accuracy of fire; dangerous magazine; C.-R.—Heavy trigger-pull.

C.-R.—Trigger-pull excessive; nose of seat too short; sights defective; misfires occasionally; button cut-off in the way in operating bolt, and magazine often unintentionally turned on when gun is used as single loader; breech mechanism works hard, liable to rust; dangerous half-cocking arrangement; hammer-head should have thumb-piece; no way to show magazine is empty; stock too large; unsuited to manual. H.—Bullet indented in entering chamber. Lee—Bullet injured in entering bore; magazine easily lost, &c.

H.—Firing-pin spring weak; sights bad; dangerous magazine; bullet strikes in entering bore, hence inaccurate shooting; reloaded ammunition works badly.

RESULTS.

Magazine guns compared—		1. With each other.			2. With the service rifle.							
		Preference.			Preference.							
					As single-loader.				For all uses.			
Division.	Department.	Lee.	Chaffee-Reece.	Hotchkiss.	Lee.	Chaffee-Reece.	Hotchkiss.	Service.	Lee.	Chaffee-Reece.	Hotchkiss.	Service.
The Pacific	California	5	0	2	1	0	0	3	1	0	0	3
	Arizona	1	0	2	0	0	0	4	0	0	2	5
	The Columbia	6	1	0	1	0	1	2	0	1	0	3
The Missouri	Dakota	3	3	5	0	0	0	1	0	0	0	4
	The Platte	7	4	8	0	0	0	6	0	0	0	9
	The Missouri	20	0	3	1	0	0	2	5	0	1	11
	Texas	3	3	3	0	0	0	2	0	1	0	7
The Atlantic	The East	10	3	3	2	0	0	1	4	1	1	4
Totals		55	14	26	5	0	1	21	10	3	4	46

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